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THE KANEVILLE ESKER, KANE COUNTY, ILLINOIS

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ABSTRACT. — A linear ridge consisting of sand and gravel, located in south-central Kane County, Illinois, was interpreted to be an esker as early as 1899.

Topographic configuration of the feature and associated landforms, sediments comprising the landform, alignment of these sediments, and nature and location of the associated materials support the eskerine interpretation.

A feature referred to as the Kaneville esker has been described by Leverett (1899, p. 284-286) and by Leighton, Powers, MacClintock and Workman (1931, p. 66-75). The location and the areal extent of the landform are also shown on maps accompanying publications by Block (1960, pl. 1); Suter, Bergstrom, et al. (1959, fig. 5); Fryxell (1927, pl. 1); and Hopkins, Mosier, et al. (1917, Soil Survey Map of Kane County, Northern Sheet). George E. Ekblaw of the Illinois State Geological Survey has suggested that the Kaneville esker might be a group of coalescing kames formed at the edge of an ice sheet (1962, personal communication). Another interpretation suggests that the Kaneville esker may have originated as a crevasse filling (Boardman, Odom, and Wilson, 1962, p. 9). The purpose of this paper is to describe the characteristics and mode of origin of the landform. However, the feature will be referred to occasionally as "the Kaneville esker" in order to avoid repetition of descriptive terms.

DISTRIBUTION AND FORM

The Kaneville esker is located in the southern part of Kane County about six miles west of Aurora, Illinois, in the extreme northeast part of the Bloomington Ridged Plain (Fig. 1), as defined by Leighton, Ekblaw, and Horberg (1948, p. 24). Specifically, the Kaneville esker extends from the NE ¼ of Sec. 15, T. 38 N., R. 7 E. to the SE ¼ NE ¼ Sec. 25, T. 39 N., R. 6 E. (Fig. 2). The feature displays an arcuate plan and may be divided into three topographic units referred to as the southeast section, the middle section, and the northwest section (Fig. 2).

The topographic form of the southeast section has been largely interpreted from the topographic map because the landform has been practically destroyed by removal of sand and gravel by man. This section appears to have consisted of several small, somewhat elongate hillocks that were from 20 to 50 feet higher than the valley of Blackberry Creek, which follows the trend of the landform for several miles. The crests of the hillocks had an elevation of about 690 to 700 feet above sea level at the extreme southeast end of the feature.

The middle section of the Kaneville esker consists of an elongate, irregularly crested ridge that is breached at several points. The ridge rises 40 to 70 feet above the adjacent plain, the height increasing to-

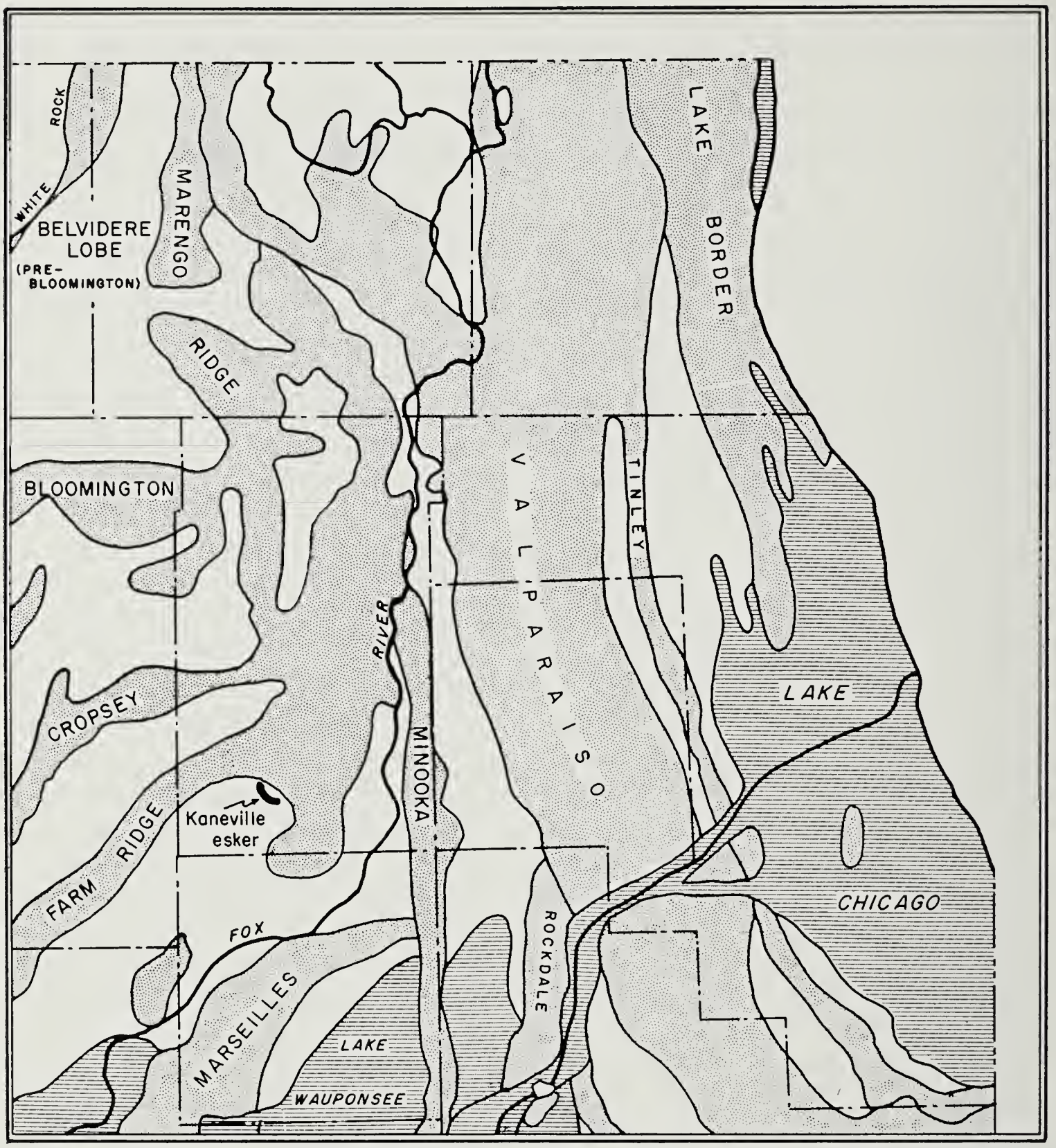

FIGURE 1. — Location of the Kaneville esker in relation to other glacial deposits in northeastern Illinois. (After Ekblaw, I.S.G.S., 1942.)

ward the northwest. The width ranges from about 400 feet to more than 600 feet, and the sides assume a maximum slope of about 25°.

The northwest section of the landform is complex and does not display the well-defined eskerine form characteristic of the middle section. This part of the feature is fan-shaped in plan and consists of a series of coalescing kame-like landforms that range from 50 to 70 feet in height.

A landform with the topographic configuration of a delta extends north and northwest from the Kaneville esker. Leverett (1899, p. 284) was the first to interpret the feature as a delta, and later Powers (Leighton, Powers et al., 1931, p. 72) agreed with Leverett's interpretation and

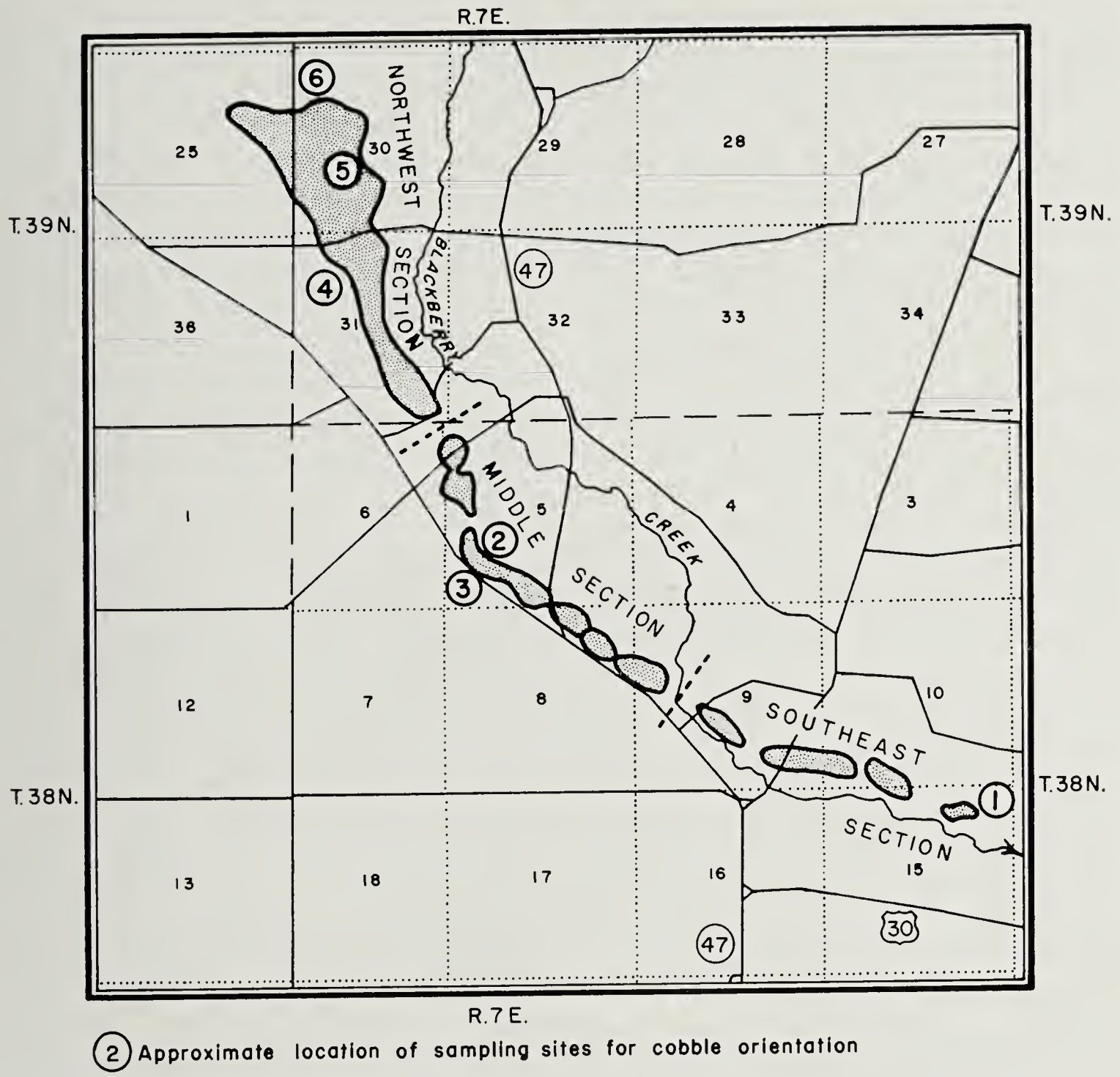

FIGURE 2. — Areal Extent of the Kaneville Esker. The shaded area represents the topographic extent of the landform.

correlated the delta with a pro-glacial lake which he called Lake Pingree. The maximum altitude of this postulated delta is approximately 810 feet. The maximum altitude of the hillocks at the extreme southeast end of the Kaneville esker is 700 feet. Thus the delta has a maximum altitude 110 feet higher than that of the hillocks which comprise the southeast part of the feature.

The linear arrangement of the landform implies lateral limitation of the area of deposition. This limitation undoubtedly resulted from the presence of glacial ice on at least one side, and possibly both sides of the deposit. If the eskerine interpretation of origin is accepted, the length and the linear pattern of the landform are satisfactorily explained. The sparsity of eskerine features in the southeast section could be accounted for by a lack of deposition especially since this area may represent the headwater of the esker stream. In addition, Powers (Leighton, Powers, et al., 1931, p. 75) ex-

pressed the belief that the southeast section was overridden by a later advance of glacial ice which could have altered any pre-existing landforms.

The middle section displays an irregular longitudinal profile and sharp crest, features that strongly suggest an eskerine origin. The northwest section appears to be closely related to the eskerine forms of the middle section but a significant topographic difference, as described previously, exists between the two sections. The northwest section may have been formed at or near the mouth of the esker stream in direct contact, at least in part, with glacial ice. This section may represent a transitional zone between the proglacial delta form to the north and west and the ice-restricted eskerine features of the middle section to the south and southeast. If this interpretation is correct, the landforms of the northwest section, although not truly eskerine in character, lend support to the proposition that the feature is actually an esker and not a group of ice-marginal kames or a crevasse filling.

Perhaps the principal objection to the eskerine interpretation is the increase in altitude between the southeast and the northwest sections of the feature. This difference in height may be explained by 1) an uphill flow of the esker stream under hydraulic pressure, 2) superimposition of englacial or superglacial stream sediments upon an uneven subglacial topography, or 3) a combination of these two possibilities.

The interpretation that the feature is ice-marginal in origin seems to have been postulated principally on the basis of 1) the arcuate plan of the landform and 2) the possibility that morainal trends to the southwest might conform to this pattern (George E. Ekblaw, 1962, personal communication). According to this interpretation, the hills which comprise parts of the landform represent frontal kames that may coalesce in places. Powers (Leighton, Powers, et al., 1931, p. 72) recognized that, on the basis of a till deposit, the southeast section was overridden by a later advance of the ice that might have altered the form of some of these kames.

The middle section of the feature is difficult to explain if the ice-marginal interpretation is accepted. The construction of ice-marginal features possessing such linear continuity and cross-sectional symmetry that are typical of this section would require conditions difficult to visualize.

The relationship between the Kaneville esker and the delta is also difficult to explain by the ice-marginal hypothesis without some explanation of the source of the meltwater and sediments that comprise the delta. Possibly the delta is not related to the Kaneville esker. However, the proximity and form of the two features seem to indicate something more than fortuitous location.

If the crevasse-filling hypothesis is accepted, the difference in altitude between the extreme ends of the landform implies a southeast flow of meltwater or superimposition onto the subglacial topography. The landforms of the southeast section offer no evidence of a southeast flow of meltwater. To the contrary, the configuration of the northwest section suggests the terminus of a meltwater stream, not a headwater area. Super-

imposition of crevasse sediments upon the subglacial topography might possibly explain the relationship between the delta and the landform but, if this did occur, the gradient along the present landform must be the reverse of the gradient present during the construction of the feature. The irregular crest of the landform is not in harmony with the crevasse-filling interpretation. The crests of crevasse fillings are usually smooth in longitudinal profile. In addition, the sharp-crested cross-sectional profile of the Kaneville esker presents a striking contrast to the flat crest which is commonly associated with crevasse fillings. The length of the landform, approximately five miles, is greater than that believed to be associated with most crevasse fillings (Flint, 1957, p. 15 and Thwaites, 1961, p. 52). The arcuate plan of the landform is also anomalous with the nearly straight trend which is typical of known crevasse fillings (Thwaites, 1961, p. 52). In almost every respect, the topographic configuration of the landform contradicts the crevasse-filling hypothesis.

Characteristics of the Sediments

Ice-contact deposits are characterized by complex stratification and cross-bedding, great variation and abrupt changes in grain size, and slumping of the sediments. Such characteristics are common in the sediments associated with the Kaneville esker.

The gross stratification of the sediments is more or less horizontal but near the flanks of the landform some bedding planes are approximately parallel to the sloping surface of the feature. In general, the sediments consist of lenses of coarse gravel which are interfingered with layers of sand. Cut-and-fill deposits are common, and cross-bedding, ranging from large to small scale, is present at numerous exposures. The dominant dip of the cross-beds is to the north and northwest.

Orientation of the long axes of fifty cobble-sized stones was determined at each of six locations. The results, graphically described in Figure 3, indicate that the flow of the depositional medium was generally parallel to the strike or trend of the landform.

The sediments consist primarily of materials larger than the size of fine sand (¼ mm.). Dolomite, believed to be derived principally from Niagaran rocks of Silurian age, comprises the bulk of the coarse sediments.

Till is found along both sides of the glacio-fluvial sediments and in some instances overlies the gravel along the flanks of the landform. At no outcrop did the writers find the till to extend completely over the water-deposited materials. However, Powers (Leighton, Powers, et al., 1931, p. 72) recognized a till overlying glacio-fluvial sediments in the southeast section but, as mentioned previously, associated the till with a later advance of the ice. Furthermore, the overlying till as described by Powers is distinctly different from the flanking till recognied by the writers. The flanking till is sandy, with dolomite comprising the bulk of the pebble content. Cobbles and boulders are rare. The color of the

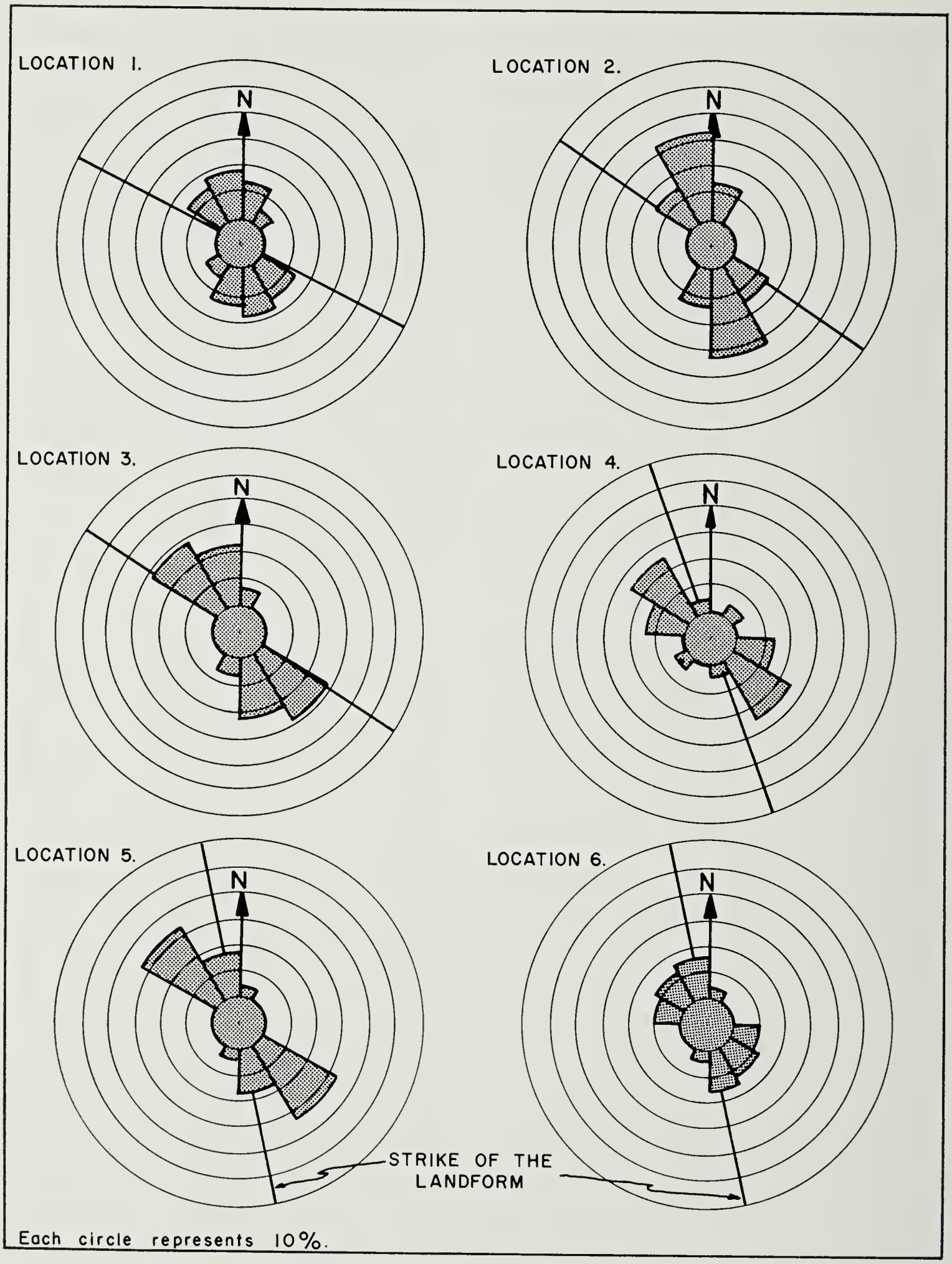

FIGURE 3. — Cobble orientation, showing the relationship of the long axis orientation to the strike of the landform.

till varies from light-brown to brown with a reddish cast. The exposed till overlying the glacio-fluvial sediments is rarely more than six feet thick. At one location along the north flank within the southeast part of the land-

form, the till is interrupted by a thin, nearly horizontal, discontinuous carbonaceous zone. The till above this carbonaceous layer is not obviously different from the till below, but it is possible that the carbonaceous zone separates two tills of different ages.

At several locations near the northwest end of the Kaneville esker, the stratified sands and gravels merge horizontally and vertically with slumped, laminated silts and clays that contain occasional pebbles and cobbles. The nature of these sediments obviously suggests deposition in calmer water than that in which the sand and gravel were deposited. The transitional contact between the fine sediments and the sands and gravels indicates that both may have been deposited by meltwater associated with an esker stream. The nature and location of the silts and clays might be explained by the periodic occurrence of unusual volumes of meltwater, which caused the stream to overflow its normal channel. During these periods of high water, sand and gravel could have been deposited in the main channel as bedload, and silts and clays which were carried in suspension by the stream could have been deposited on the uneven surface of the adjacent ice. Under these conditions a transitional zone may have been present between the coarse and fine sediments. The occasional coarse particles in the fine sediments might have melted out from blocks of floating ice. A decrease in the volume of water would have left the clays and silts resting, at least in part, on the flanking ice. Subsequent melting of the supporting glacial ice would have permitted the fine sediments to be superimposed directly on the underlying glacial drift. This interpretation can account for both the contorted laminations of the silts and clays and for the gradational contact between the coarse and fine sediments that exist within this part of the feature.

The carbonaceous material that exists within the silts and clays probably represents organic matter present in the general depositional environment. The character and concentration of the carbonaceous matter in such a small area make it doubtful that the material represents a pre-existing organic deposit that was reworked by ice and then redeposited by meltwater. In the opinion of the writers, some form of vegetation probably existed within the glacial environment at the time the feature was being formed.

Summary and Conclusion

The eskerine theory most plausibly explains the origin of the Kaneville esker. The topographic configuration of the landform presents the most convincing evidence for the acceptance of this interpretation. The linear pattern and irregular crest are typical of eskerine forms. Furthermore, this interpretation is supported by certain sediment characteristics, including the alignment of sedimentary particles generally parallel to the trend of the landform and the northwesterly dip of the crossbedding. The till overlying both flanks of the feature suggests that glacial ice existed along both sides of the landform during its formation. The location and the altitude of the delta are most easily explained

by the presence of an esker stream flowing to the northwest. Thus, on the basis of the evidence presented, this landform merits its designation as an esker.

Acknowledgments

The writers wish to thank George E. Ekblaw and I. E. Odom of the Illinois State Geological Survey and W. E. Powers of Northwestern University for helpful comments and suggestions.

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FOODS OF THE TOAD, *BUFO WOODHOUSEI FOWLERI* HINCKLEY

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ABSTRACT. — The stomach contents of 504 *Bufo woodhousei fowleri*, from southern Illinois, were analyzed. Three phyla of invertebrates were represented in the 497 stomachs containing food. The Mollusca (occurring in 1.2% of the stomachs with food) and Annelida (0.4%) were of minor importance, and of the Arthropoda the classes Insecta (100.0%) and Arachnida (12.9%) were the principal groups. Eleven orders and sixty-seven families of insects were identified; the orders Coleoptera (92.0%) and Hymenoptera (72.8%) were by far the most frequently represented groups. Because of the abundance and variety of prey utilized, food supply probably does not constitute an important factor in population control of Fowler's toad. The diet of Fowler's toad is determined principally by relative availability of prey items, and selectivity of prey is a factor of minor importance. Major aspects of the diet are much the same in southern Illinois, Georgia, and Oklahoma, except that a greater variety of foods is utilized in the first two states, a phenomenon attributed to greater faunal diversity in those areas.

Partly because of their supposed economic value (for example, Bragg, 1943; Garman, 1901; Kirkland, 1897, 1904), the food habits of North American toads (*Bufo*) have received more attention than most other groups of amphibians. Few writers, however, have based their work on adequate samples; for this reason our knowledge of dietary patterns is not as extensive as might be expected. Most of the important literature on the feeding of bufonids has been reviewed by Smith and Bragg (1949), Hamilton (1954), and Bush and Menhinick (1962).

The data to be presented represent a segment of a study of the biology of *Bufo woodhousei fowleri* Hinckley in southern Illinois. Until recently, analyses of the food habits of Fowler's toad were based on small samples; however, Smith and Bragg (1949) reported on 560 specimens of a related subspecies, *B. w. woodhousei* Girard, in Oklahoma. As our data were being compiled, Bush and Menhinick (1962) published on the stomach contents of 111 *B. w. fowleri* from Georgia. These studies provide an opportunity to compare the diet of *B. woodhousi* from three widely separated localities—Oklahoma, Illinois, and Georgia.

MATERIALS AND METHODS

A total of 504 stomachs of *B. w. fowleri* was examined (Table 1), representing specimens from Jackson, Union, and Williamson counties, Illinois, for June through September, 1958, and April through May, 1959. Specimens were collected in a variety of habitats, but many came from weedy, recently disturbed sections of new residential areas, agricultural areas, and roadsides; no collecting

was done around potential breeding waters. Stomachs were removed and stored in alcohol until examination. The individual stomach was opened along its greatest curvature and the contents emptied into a small dish of water. Food items were segregated under magnification; materials not readily identifiable were stored in alcohol or mounted on pins or slides for later determination. Tabulation of data was limited to percent frequency of occurrence; the many small food items and miscellaneous insect parts made it virtually impossible to obtain reasonably accurate volumetric measurements, or, in many cases, even counts of individual items.

Foods in Southern Illinois

Food items representing three phyla of invertebrates (Mollusca, Annelida, and Arthropoda) were present in the stomachs of 497 Fowler's toads; two additional stomachs contained only unidentifiable matter and five were empty (Tables 1 and 2). Mollusks occurred in only 1.2 percent of those containing food, and annelids in only 0.4 percent, hence the arthropods (100% occurrence) comprised the important group. Five classes of arthropods were recorded; the Insecta occurred in every stomach that contained food, being represented by at least 11 orders and 69 families. The orders Coleoptera (92.0%) and Hymenoptera (72.8%) actually comprised the major portion of the diet (Figs. 1 and 3).

Table 1.—Numbers and conditions of stomachs by months for *Bufo woodhousei fowleri* in southern Illinois.

Month	Number with matter	Number empty	Total
April.....	21	0	21
May.....	115	2	117
June.....	46	1	47
July.....	40	0	40
August....	125	2	127
September.	100	0	100
Unknown .	52	0	52
Totals....	499*	5	504

* Of which 497 stomachs contained food material, and two only extraneous matter.

Of 32 families of Coleoptera identified, the Carabidae (63.8%), Curculionidae (37.4%), Chrysomelidae Scarabaeidae (29.8%), Elateridae (19.3%), Coccinellidae (18.7%), Cantharidae (13.5%), and Staphylinidae (12.9%) occurred most frequently (Table 2 and Fig. 2). Adult beetles were recorded in 91.3 percent of the stomachs and larvae in 16.5 percent. Only in the case of Cantharidae were larvae (9.9%) more

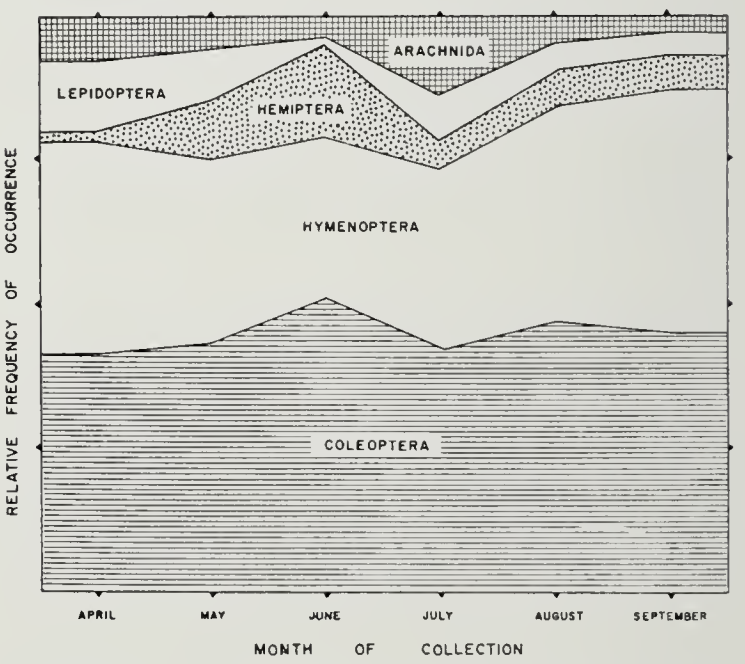

Figure 1. — Relative utilization of major food groups by *Bufo woodhousei fowleri* in southern Illinois (June - September, 1958 and April - May, 1959). The graph does not show cumulative percentage, but rather the width of each segment reflects frequency of utilization of a food group *relative* to other groups on the graph.

TABLE 2.—Invertebrate groups utilized as food by *Bufo woodhousei fowleri* in southern Illinois.

Food	Month of collection and number of stomachs								Percent frequency of occurrence
	April 21	May 113	June 46	July 40	August 125	September 100	Unknown 52	Total 497	
INSECTA	21*	113	46	40	125	100	52	497	100.0
Undetermined	3	5	6	4	24	9	6	57	11.5
COLEOPTERA	20	113	44	39	109	90	42	457	92.0
Undetermined	..	...	11	7	11	7	..	36	7.2
Adults	20	113	44	39	108	90	40	454	91.3
Larvae	..	19	9	3	25	12	14	82	16.5
Carabidae	15	95	38	32	70	46	21	317	63.8
Curculionidae	17	82	17	14	26	22	8	186	37.4
Chrysomelidae	7	34	12	8	51	37	21	170	34.2
Scarabaeidae	15	49	14	16	25	21	8	148	29.8
Elateridae	7	39	11	9	14	12	4	96	19.3
Coccinellidae	..	27	9	9	17	18	13	93	18.7
Cantharidae	..	15	5	4	23	12	8	67	13.5
Staphylinidae	4	9	2	5	20	14	10	64	12.9
Lampyridae	..	7	..	..	1	5	1	14	2.8
Histeridae	..	2	..	1	2	1	1	7	1.4
Nitidulidae	..	1	1	..	3	..	1	6	1.2
Meloidae	..	..	..	1	3	1	..	5	1.0
Tenebrionidae	..	2	1	2	..	..	..	5	1.0
Cleridae	..	3	..	1	..	..	..	4	0.8
Cucujidae	..	..	..	..	2	..	1	3	0.6
Heteroceridae	..	..	..	..	3	..	..	3	0.6
Byrrhidae	..	..	..	..	..	..	2	2	0.4
Cerambycidae	..	..	1	1	..	..	..	2	0.4
Cicindelidae	..	..	..	..	..	1	1	2	0.4

TABLE 2.—Continued.

Food	Month of collection and number of stomachs								Percent frequency of occurrence
	April 21	May 113	June 46	July 40	August 125	September 100	Unknown 52	Total 497	
Erotylidae	..	2	..	..	..	..	..	2	0.4
Lathridiidae	..	..	..	..	1	1	..	2	0.4
Alleculidae	..	..	..	1	..	..	..	1	0.2
Anthicidae	..	..	..	..	..	..	1	1	0.2
Anthribidae	..	..	..	1	..	..	..	1	0.2
Bostrichidae	..	..	1	..	..	..	..	1	0.2
Bruchidae	..	..	..	..	1	..	..	1	0.2
Hydrophilidae	..	..	..	..	..	1	..	1	0.2
Monotomidae	..	..	..	..	..	1	..	1	0.2
Omophronidae	..	..	1	..	..	..	..	1	0.2
Ptilodactylidae	..	..	..	1	..	..	..	1	0.2
Scaphidiidae	..	..	..	..	1	..	..	1	0.2
Scolytidae	..	..	..	..	..	..	1	1	0.2
HYMENOPTERA	18	85	24	29	85	75	46	362	72.8
Undetermined	1	7	1	2	9	12	1	33	6.6
Formicidae	17	81	20	28	78	70	45	339	68.2
Vespidae	..	1	3	4	3	2	1	14	2.8
Ichneumonidae	..	3	1	3	..	..	..	7	1.4
Megachilidae	..	..	..	1	2	1	..	4	0.8
Sphecidae	..	..	..	1	..	1	2	4	0.8
Braconidae	..	..	1	1	..	..	1	3	0.6
Mutillidae	..	..	1	..	2	..	..	3	0.6
Apidae	..	..	..	..	..	1	..	1	0.2
Tenthredinidae	..	..	..	..	..	1	..	1	0.2
HEMIPTERA	1	26	14	5	14	11	7	78	15.7

TABLE 2.—Continued.

Food	Month of collection and number of stomachs								Percent frequency of occurrence
	April 21	May 113	June 46	July 40	August 125	September 100	Unknown 52	Total 497	
Undetermined	..	3	2	..	4	2	2	13	2.6
Cydnidae	..	9	13	1	1	1	1	26	5.2
Pentatomidae	1	15	2	1	3	2	2	26	5.2
Lygaeidae	..	..	..	2	2	4	3	11	2.2
Coreidae	..	3	..	..	3	1	1	8	1.6
Corixidae	..	..	..	1	4	1	1	7	1.4
Nepidae	..	..	..	..	1	1	..	2	0.4
Reduviidae	..	1	..	..	..	..	..	1	0.2
LEPIDOPTERA	6	24	2	8	13	9	7	69	13.9
Undetermined	2	8	1	3	5	5	3	27	5.4
Adults	1	..	1	1	..	3	1	7	1.4
Larvae	6	24	1	7	13	6	6	63	12.7
Noctuidae	4	15	..	1	6	2	3	31	6.2
Arctiidae	..	..	..	2	1	1	1	5	1.0
Geometridae	..	1	1	2	1	..	..	5	1.0
Psychidae	..	..	..	..	..	1	..	1	0.2
ORTHOPTERA	3	4	6	7	11	6	5	42	8.4
Undetermined	..	..	..	1	..	1	..	2	0.4
Tettigidae	2	3	3	4	5	1	1	19	3.8
Locustidae	..	1	3	..	4	2	3	13	2.6
Gryllidae	..	..	1	1	2	2	1	7	1.4
Blattidae	1	..	..	1	..	..	..	2	0.4
Tettigoniidae	..	..	..	..	..	1	..	1	0.2

TABLE 2.—Continued.

Food	Month of collection and number of stomachs								Percent frequency of occurrence
	April 21	May 113	June 46	July 40	August 125	September 100	Unknown 52	Total 497	
HOMOPTERA	..	4	2	2	5	13	4	30	6.0
Cicadellidae	..	3	2	2	5	12	3	27	5.4
Membracidae	..	1	..	..	..	1	1	3	0.6
Fulgoridae	..	..	..	..	..	1	..	1	0.2
DIPTERA	..	3	..	2	3	6	3	17	3.4
Undetermined	..	..	..	2	3	3	2	10	2.0
Tipulidae	..	1	..	1	1	1	..	4	0.8
Tachinidae	..	1	..	..	..	1	..	2	0.4
Culicidae	..	1	..	..	..	..	..	1	0.2
Stratiomyidae	..	..	..	..	..	..	1	1	0.2
Syrphidae	..	..	..	..	..	1	..	1	0.2
EPHEMEROPTERA	..	..	..	..	7	..	..	7	1.4
NEUROPTERA (Chrysopidae)	..	..	..	..	..	2	..	2	0.4
PLECOPTERA	..	..	..	..	1	..	..	1	0.2
DERMAPTERA (Labiidae)	..	..	..	..	..	1	..	1	0.2
ARACHNIDA	5	20	4	12	11	6	6	64	12.9
ARANEAE	4	19	4	12	11	6	6	62	12.5

TABLE 2.—Concluded

Food	Month of collection and number of stomachs								Percent frequency of occurrence
	April 21	May 113	June 46	July 40	August 125	September 100	Unknown 52	Total 497	
ACARINA	1	1	..	..	..	..	..	2	0.4
CRUSTACEA (ISOPODA)	5	15	..	2	12	2	1	37	7.4
DIPLOPODA	..	16	..	..	1	3	..	20	4.0
CHILOPODA	..	1	1	1	1	1	..	5	1.0
GASTROPODA	..	1	..	..	2	2	1	6	1.2
Snails	..	1	..	..	1	2	1	5	1.0
Slugs	..	..	..	..	1	..	..	1	0.2
OLIGOCHAETA (Earthworms)	..	..	..	..	1	1	..	2	0.4

* All but the last column show numbers of stomachs in which given food items occurred.

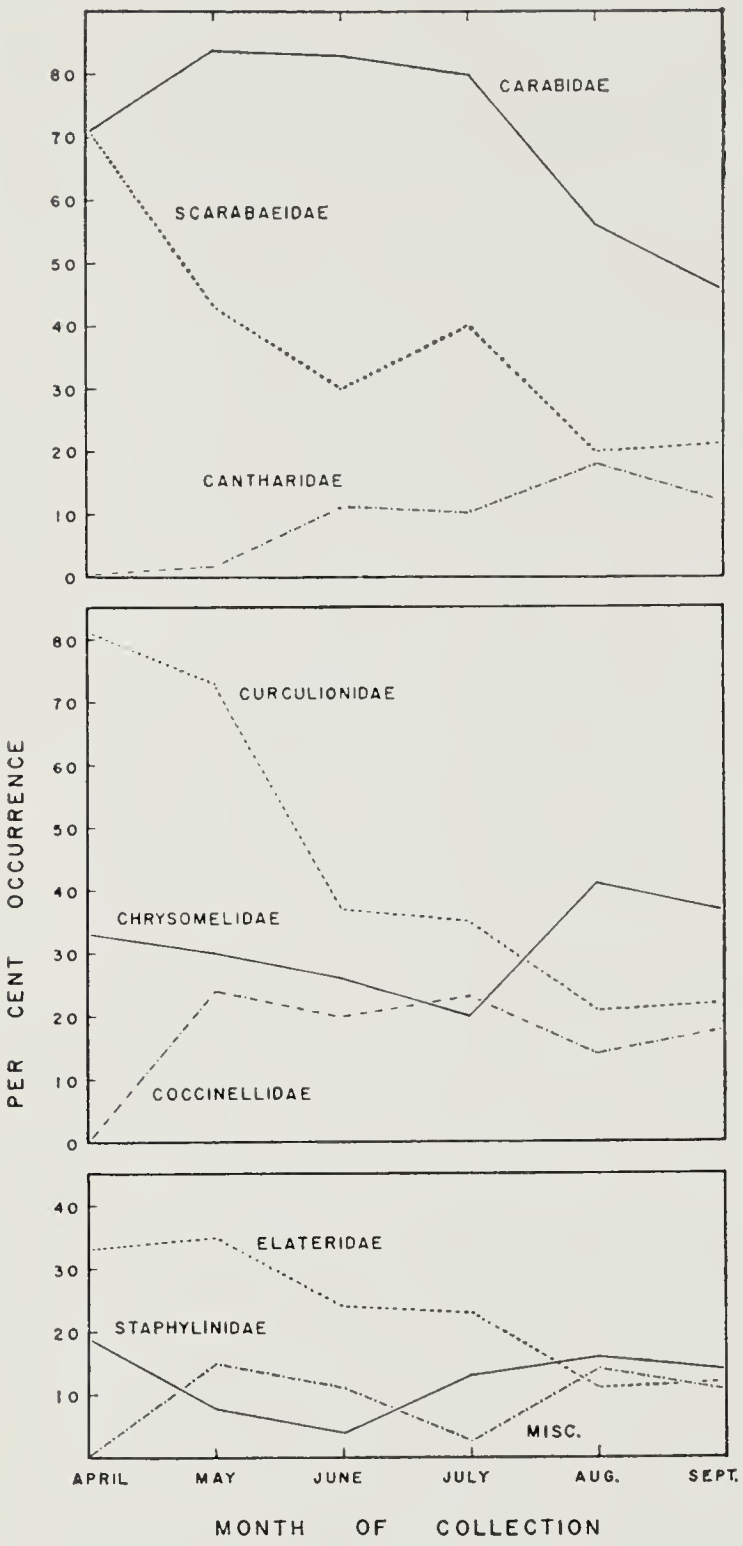

Figure 2. — Monthly variation in the utilization of some families of Coleoptera by *Bufo woodhousei fowleri* in southern Illinois (June - September, 1958 and April - May, 1959).

frequently utilized than adults (3.6%).

Of the Hymenoptera, Formicidae appeared in 68.2 percent of the samples in contrast to 2.8 percent for the next most frequent family, the Vespidae (Table 2). More than a dozen types of ants were observed, although identification below family level was not attempted.

Hemiptera yielded a 15.7 percent occurrence, Lepidoptera (mostly larvae) 13.9 percent, Orthoptera 8.4 percent, Homoptera 6.0 percent, and Diptera 3.4 percent. Four other orders of insects each appeared in less than 2.0 percent of the sample. The Arachnida, mainly spiders, was the most frequently occurring (12.9%) of the non-insect prey.

Although no special attempt was made to relate foods eaten with the type of habitat from which toads were collected, it was generally apparent that such a relationship existed. The majority of specimens came from recently disturbed areas such as residential subdivision development and rural roadsides, where such plants as smartweed (*Polygonum*), ragweed (*Ambrosia*), lamb's quarter (*Chenopodium*), pigweed (*Amaranthus*), and isolated clumps of foxtail (*Setaria*) and barnyard grasses (*Echinochloa*) dominate the vegetational pattern. In such sites, the vegetation creates shaded, cool, moist environments alternating with extensive patches of bare ground. This kind of habitat seemed to be preferred not only by the toads but also by many species of invertebrates (especially ants and certain beetles), as was evident from field observation as well as examination of stomach contents. Such habitats provide excellent places for daytime hiding and also opportunity for longer feedings periods, as light intensity at ground level is markedly reduced in the morning and afternoon. These conditions of the habitat surely enhance the feeding opportunities for resident toads, but introduce some bias into the study, inasmuch as somewhat specialized

conditions are emphasized while other habitats, such as forests, are poorly represented. For example, toads were not collected at breeding sites and, consequently, very few aquatic or semiaquatic insects were found in the stomachs; but Gehlbach and Collette (1959) found rather high percentages of aquatic insect larvae (Coleoptera: Dytiscidae 7.7%, Hydrophilidae 7.7%; Diptera: Stratiomyiidae 15.4%) in a series of 13 *Bufo w. woodhousei* from Nebraska, because their sample was (by inference) collected at or near breeding waters.

Factors to be acknowledged in analyzing foods used are increased food requirements as a result of fasting during hibernation and of preparing for breeding activities, especially in the case of females. Smith and Bragg (1949 :342-343) in their study of *Bufo w. woodhousei* in Oklahoma, noted that adult females consumed much more than adult males during spring and summer months. Analyses of such results must account for the fact that males spend a longer period in breeding activities and thus may have fewer feeding opportunities; this does not, however, account for the greater food utilization by females following breeding activities. One might assume that females require greater food supplies in order to compensate for physiological demands related to egg production. Because this physiological stress may actually begin well in advance of hibernation, females may feed more heavily in summer in order to compensate for such demands during and immediately following hibernation. The fact that females also attain a larger body size is important, but probably not the only factor involved, as just indicated. Certainly, the factors responsible for greater food utilization by females bear further investigation.

Annual availability and hence utilization of food items are dynamic phenomena in each type of habitat. This reflects aspects of reproduction and life cycles of the prey, relative abundance of each species of prey, and conditions of the environment at any given time of the season. These features are reflected in the diet of *Bufo w. fowleri*, being best shown by the use made of several families of Coleoptera (Fig. 2). To illustrate, the family Carabidae was extensively utilized as food during April through September, with the greatest frequency of occurrence being May through July. During the time of maximum utilization of the carabids, there was a general decrease in the relative occurrence of several other families of beetles (Fig. 2). Because many beetles tend to show population increments comparable to those of carabids, it might be concluded that carabids were the preferred foods. We think the answer is not so simple, and that the carabids, being a readily available food, were proportionately more abundant than other forms. Certainly the Carabidae are among the most abundant of terrestrial beetles in southern Illinois. The decline in utilization of the Carabidae after July seems compensated for by increased utilization of other forms. A heavy spring utilization and a late summer and early fall decline in some kinds of Coleoptera (Fig. 2) probably are not due to a decrease in numbers of prey, for

biological activities in late spring and early summer result in large fall populations of many kinds of beetles (Dr. Milton W. Sanderson, verbal communication); mortality factors in over-wintering beetle populations somewhat reduce the number by spring. The answer probably lies in differential activities of prey and/or predator, and in the fact that juvenile toads represent much of the late summer and fall samples; although little qualitative difference has been noted between the diets of juvenile and adult toads, (Smith and Bragg, 1949) it is obvious that juveniles cannot ingest as large objects as can adults (Bragg, 1948). In spite of marked fluctuations in the utilization of various families of beetles, it is of interest that the Coleoptera remained notably constant, relative to other groups, in the degree to which it was utilized by toads throughout their season of activity (Fig. 1). The Hymenoptera also showed relative month-to-month stability. The Coleoptera and Hymenoptera are without question the major dietary constants of Fowler's toad.

A variety of non-prey items were found in the stomachs (Table 3), the most frequent of which were various plant materials (mainly dead leaf fragments, grass blades, twigs, and small blossoms). Most of the vegetation was probably ingested along with animal prey, but some possibly represents active "capture" of falling or wind-blown items; that this sometimes happens is demonstrated by observations made by Harold Lyon (cited in Oliver, 1955:198) in the Hawaiian Islands, where *Bufo marinus* snapped up falling blossoms from Strychnine Trees and subsequently died of strychnine poisoning! A single mammal hair and a small bird feather in stomachs of Fowler's toads do not suggest predation on vertebrates, as there were no other associated remains. Toads are not normally predators of vertebrates but, contrary to the claims of some authors, there are records of predation by *Bufo* on other vertebrates. Smith and Bragg (1949:347) reported the ingestion of a small lizard by a captive *B. w. woodhousei;* Bragg (1960) observed a captive *B. houstonensis* swallow a small spadefoot toad, and thought that cannibalism also occurred; Hazelwood (1949) observed the ingestion of a snake by *B. bufo;* King (1960) had a captive *B. w. woodhousei* that ate a small turtle. As sight of moving prey seems to be the primary triggering mechanism for feeding, it seems likely that occasional predation on small vertebrates occurs in nature.

TABLE 3.—Non-prey and unidentified material from the stomachs of *Bufo woodhousei fowleri* in southern Illinois.

Item	Number of Stomachs (Sample Size – 499)	Percent Frequency of Occurrence
Vegetable debris	94	18.8
Rocks	29	5.8
Undetermined matter	21	4.2
Castoff *Bufo* skin	8	1.6
Nematodes	7	1.4
Bird feather	1	0.2
Mammal hair (1)	1	0.2

Availability Versus Selectivity

Bufo woodhousei, like most other vertebrate predators (for example, the red fox, Scott and Klimstra, 1955), within the limits of its ability to take food, awareness of potential food, and to a limited extent food preferences, is largely regulated in its feeding by the relative availability of foods. The occurrence of wasps, velvet ants, blister beetles, and stinkbugs (items obnoxious to some predators) in the diet of this species suggests that few insects are not acceptable. Considering the numerical abundance of invertebrates and their wide occurrence, food supply is probably rarely, if ever, a limiting factor of this toad. Nutritional aspects of various foods, however, have not been investigated. Some factors influencing the diet of Fowler's toad have been discussed in preceding paragraphs; additional considerations, and the relative importance of availability versus selectivity of food items, are discussed below.

Unquestionably, the degree of activity of prey species (and predator) is important when considering foods utilized. Adult dipterons and lepidopterons, mostly strong flyers, are rare in the diets of this and other species of toads, although such insects are numerically abundant and many are nocturnal. Certain fast moving terrestrial insects, such as crickets and roaches, although relatively abundant in habitats frequented by Fowler's toads, are infrequently eaten in nature (Table 2), and often escape capture even in terraria (Martof, 1962a). In contrast, beetles and ants, the main food items, are mostly infrequent flyers and many are common ground dwellers, factors that probably account for the high frequency of occurrence of these insects in the diet of toads generally.

The time of feeding also places restrictions on available foods. Toads in general are well known for their crepuscular and nocturnal habits (although there is some seasonal and ontogenetic variation in diel cycles). Martof (1962a) found that captive Fowler's toads can feed in very dim light and complete darkness, and that feeding is triggered by accidental contact with the prey as well as by visual stimulation. Many abundant diurnal insects (*e.g.* grasshoppers and some bugs) are not often eaten, whereas insects mostly active at night (*e.g.* carabid beetles) or active night and day (*e.g.* ants) are well represented in the diet.

Stomachs of Fowler's toads were only occasionally gorged with single species of insects, indicating times when the toads had taken advantage of food concentrations. As mentioned by Smith and Bragg (1949:345) for *B. w. woodhousei,* concentration on single species of prey seems to be a rare event. Large concentrations of only one kind of prey probably are not often encountered by toads, except in agricultural areas where there are uniform stands of vegetation; Pack (1922) observed a concentration of young *B. woodhousei* feeding almost exclusively on an abundant supply of sugar-beet webworms. None of the toads used in the present study were collected under street lights, although *B. w. fowleri* and *B. w. woodhousi* do congregate at such sites of ready food

supply (Ferguson, 1960, 1963; Smith and Bragg, 1949:336) and, under certain conditions, probably engorge on one or a few species of prey. Pearse (1910) and Martof (1962b) demonstrated that Fowler's toad is positively phototropic; the observation that some species of toads react differently to light (Smith and Bragg, 1949:336) invites further experimetnation.

As Fowler's toad feeds regularly on very small insects, as well as large ones, it apparently has good vision. Morphological features of the toad that prohibit side or backward head movements may somewhat restrict the range of vision, but this is probably largely compensated by the location and functional aspects of the eyes. One of us (Myers) has seen a Fowler's toad repeatedly lap up steel shot that were rolled to it, thereby attesting to indiscriminant feeding and the importance of vision in the feeding process. Kaess and Kaess (1960) demonstrated for *Bufo terrestris* that ingestion of non-living food (hamburger) could be induced by either real or apparent motion of the food. Fowler's toads are possibly alerted by sounds made by potential prey (Martof, 1962a), but olfaction does not seem an important factor in selection of food items, although olfactory powers are seemingly well developed (Martof, 1962a, c). Touch is another stimulus for feeding, as blinded Fowler's toads will eat insects with which they come in contact (Martof, 1962a).

We agree with Hamilton (1954), Berry and Bullock (1962), Smith and Bragg (1949), and others, that availability of prey is the important factor, and that toads are potential predators of most invertebrates which are small enough to be captured.

We do not claim that toads of the genus *Bufo* do not exhibit some selectivity in kinds of foods eaten, but, except for the cases of a few species of highly noxious insects (see below), there is a decided lack of convincing evidence for selectivity. Cott (1957:297-299) contrasted stomach contents of *Bufo bufo* and *Rana temporaria* from the same habitat, and concluded that differences in foods eaten were due to differences in food preferences. Similarly, Inger and Marx (1961:25-26) noted that African *Bufo melanopleura* and *B. ushoranus* ate more Isoptera and Acarina than the larger *B. regularis* and *B. funereus,* and that Acarina was not eaten by some small species of *Phrynobatrachus* to the same extent as by *Bufo* spp. in the same habitat; they concluded (p. 25) that "Selectivity, as well as availability, plays a role in predation . . ." Such data can be taken as indications of food selectivity, but it seems just as probable that they reflect differences in microhabitat utilization, times of feeding, or foraging behavior. Because of these and other variables, comparisons of stomach contents are not the best indications of food preferences. As stated by Smith and Bragg (1949:336), "differences in habits and movements . . . give differential opportunities for food capture and thus must be taken into account in analyzing stomach contents. Only in this way are we to avoid ascribing to food selection differences in the foods eaten which may be due only to availability of the food objects."

Insects having aposematic colors

(*e.g.* wasps of the family Vespidae) or behavior, or those having noxious secretions (*e.g.* blister beetles, Meloidae; stinkbugs, Pentatomidae) are sometimes acclaimed as being immune from predation. This is true only in a relative sense, for there is no reason to believe that such animals are immune from *all* predators, or that they always enjoy *complete* protection from any single predator. We suspect that the utilization of such insects (Table 2) depends in large part on their availability to toads; many of these insects are diurnal, resting in vegetation above ground at night, and hence are not often available. Smith and Bragg (1949:347) noted that the stings of scorpions did not protect them from toads, and that the outside walls of many toad stomachs were bristly from the stings of mound-building ants. Nevertheless, there is proof that toads can learn to recognize and refuse to accept certain kinds of unpalatable prey. Brower et al. (1960) demonstrated that *B. terrestris* could learn to reject bumblebees and their robberfly mimics; Cott (1936) described the reactions of *B. bufo* to hive bees. Noble (1954:415) "found in the laboratory that toads could learn after a single experience to avoid an obnoxious insect," but unfortunately never published the details of his experiments. Haber (1926:208) observed a toad trying to disgorge a stinkbug; it seems likely that many small but potentially obnoxious items are swallowed too fast for their properties to become apparent to the toad, but that larger objects which offer difficulties of ingestion might be voided.

Earthworms are generally available to toads after hard rains, but only two were found in stomachs of *B. w. fowleri* in southern Illinois. Dickerson (1937:85) and Smith (1961:77) indicate that earthworms are not very acceptable foods to captive *B. americanus* and *B. w. fowleri*, respectively. Smith and Bragg (1949:341) thought that Oklahoma toads (including *B. woodhousei*) generally avoid earthworms even when these are readily available in nature. Thus, there is some indication for negative selection of earthworms by some species of toads. Even a high degree of negative selection of earthworms and certain noxious insects would probably have little important bearing on the diets of toads, when one considers the wide variety and abundance of acceptable prey.

Geographic Variation

There is seemingly little geographic variation in major aspects of the diet of *Bufo woodhousei fowleri*. Frequencies of occurrence of the major food groups utilized in southern Illinois, and the vicinity of Athens, Clarke County, Georgia (Bush and Menhinick, 1962), are compared in Fig. 3; the differences are seen to be relatively slight and the similarities pronounced. A similarity is also found in the most commonly occurring families of beetles in each sample. Bush and Menhinick (pp. 111-112) give as the most important families the Carabidae, Curculionidae, Staphylinidae, Elateridae, Scarabaeidae, Chrysomelidae, Coccinellidae, and Trogidae. With the exception of the Trogidae, which was not represented in the Illinois sample, these families fairly well

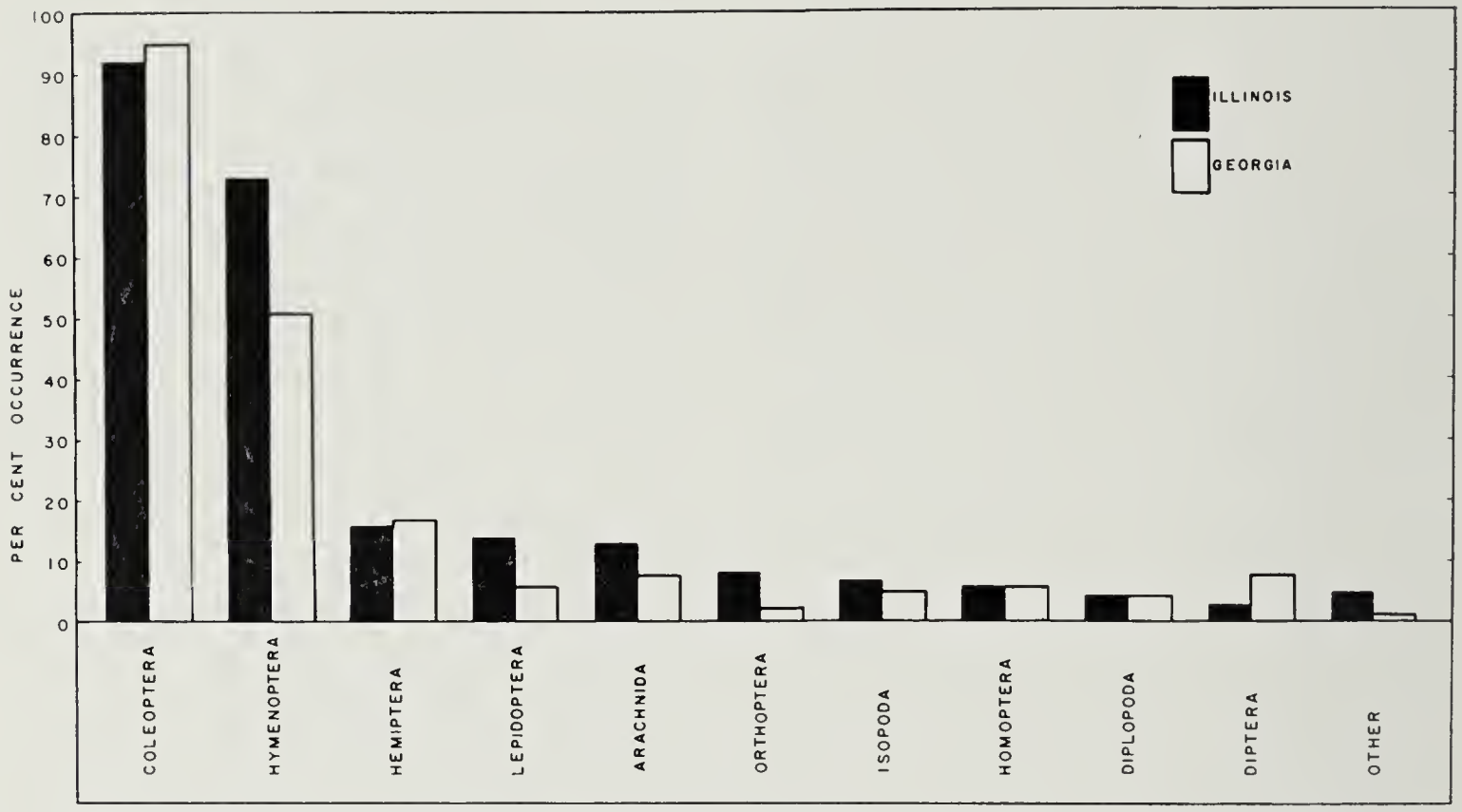

Figure 3.—Comparative utilization of foods by *Bufo woodhousei fowleri* in southern Illinois and northern Georgia. Data for the latter state from Bush and Menhinick (1962).

match the first eight families listed in Table 2. More specific differences would undoubtedly be found were comparable data available for lower taxa (genera and species) of food groups. Although Bush (1959) reported on only 18 specimens, his data for Kentucky *fowleri* are similar to the results from Illinois and Georgia. Other authors have reported on too few specimens to allow reasonable comparison.

Smith and Bragg (1949) studied a large sample (560 specimens) of *B. w. woodhousei* from Oklahoma, but, unfortunately, their results cannot be compared directly because of our different methods of data tabulation. However, their volumetric data suggest that not only the same orders, but also the same families of insects as those recorded for *B. w. fowleri* are of greatest importance. As in Illinois and Georgia, Coleoptera, especially the Carabidae, and Hymenoptera, especially the Formicidae, are the main food groups in Oklahoma, and spiders are the most important of the non-insect foods.

Although there may be little geographic variation in the utilization of major food groups by *Bufo woodhousei*, it seems plausible that the effects of latitude, major vegetational units, and other environmental factors influence the *variety* of prey available in any one geographic region. The Coleoptera, as the major food group and with its many families, offers perhaps the best test of the above hypothesis. Smith and Bragg (1949:336-337) recorded 17 families of Coleoptera from a sample of 560 *B. w. woodhousei* in Oklahoma; Bush and Menhinick (1962) reported 12 families of Coleoptera from 111 *B. w. fowleri* in Georgia; 32 families of Coleoptera were found in the sample of 504 *B. w. fowleri* from southern Illinois. These figures break down roughly into nine stomachs per coleopterous family for

Georgia, 16 stomachs per family for Illinois, and 33 stomachs per family for Oklahoma. The Illinois and Georgia data would probably become more similar at comparable sample sizes; the Oklahoma data are quite dissimilar from those of Illinois, and probably dissimilar to about the same magnitude from the Georgia data at comparable sample sizes. Georgia and southern Illinois lie well within the great Eastern Deciduous Forest; Oklahoma lies on the western fringe of this region. The greater variety of prey utilized by the Georgia and Illinois *Bufo* is taken as a reflection of the greater faunal diversity in those areas, as compared with a more depauperate fauna in the forest-edge habitats of Oklahoma.

Acknowledgments

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NEW DISTRIBUTIONAL RECORDS OF AQUATIC VASCULAR PLANTS FROM SOUTHERN ILLINOIS

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ABSTRACT. — Investigation of aquatic environments in the twenty-three southern counties of Illinois has yielded 217 county distributional records of vascular plants. A short discussion of geographical distributions pertaining primarily to southern Illinois accompanies the specimens cited in the annotated checklist.

Aquatic habitats were investigated during the summer of 1963, to update and to extend the distributional ranges of hydrophytic and amphibious vascular plants in southern Illinois.

In this paper, southern Illinois is defined as the twenty-three most southern counties from Wabash County west to St. Clair County and south to State of Kentucky. Thus, this part of the state at its greatest width and length encompasses an area approximately 144 miles wide and 106 miles long, giving the lower end of Illinois a wedge-shaped appearance. These twenty-three counties, which are bordered on the west by the Mississippi River and on the south and east by the Ohio and Wabash Rivers, respectively, comprise a total land mass of 9,496 square miles (Fig. 1).

ECOLOGICAL CONSIDERATIONS

With a yearly mean rainfall of 43 (40-46) inches (Changnon, 1963) and with relatively impervious clay soils, southern Illinois has numerous natural and artificial impoundments and streams. In recent years, emphasis has been placed upon the creation of man-made storage reservoirs, farm ponds, and lakes, such as Lake Murphysboro, Pounds Hollow Lake, Lake Glendale, Washington County Conservation Lake, Little Grassy Lake, and Harrisburg North Reservoir. These recently impounded waters provide an excellent opportunity for aquatic plants to extend their ranges. The authors concentrated upon visiting some of the major water areas in each county. Most frequently investigated aquatic areas and moist supralittorals, in their decreasing order of emphasis, are lakes, water-storage reservoirs, swamps, farm ponds, roadside ditches, strip pits, and an occasional lotic habitat.

Many of the eutrophic lakes of southern Illinois often possess a similar flora. Associated plants include *Nelumbo lutea, Polygonum* spp., *Potamogeton americanus, Naias guadalupensis, Juncus* spp., *Carex* spp., *Sagittaria latifolia,* and *Cephalanthus occidentalis* which typically inhabit long standing waters and adjacent moist shorelines (Fig. 2). Newer impoundments (for example,

FIGURE 1. — Map of southern Illinois study area showing the counties and the bordering rivers.

Washington County Conservation Lake and Devil's Kitchen Lake) are characterized by pioneer species, such as *Potamogeton diversifolius, Naias minor, Jussiaea diffusa,* and the common emergent, *Typha latifolia.*

The aquatic vegetation of swampy areas represents a unique lentic environment, since in no other community are more typically associated plants confined to a single habitat. Mermet Swamp, a 690 surface acre natural impoundment, located in Mermet Lake Conservation Area (Massac County), represents such a station which apparently has not previously been botanized with respect to the hydrophytic vascular plants. Some of the unusual county records from this station include the predaceous blatterworts (*Utricularia vulgaris* and *U. gibba*), fanwort (*Cabomba caroliniana*), and the gelatinous-leaved watershield (*Brasenia schreberi*). The sponge plant or frogbit, (*Limnobium spongia*) and various duckweeds are found drifting on the stagnant surface waters. Although present, species of *Wolffia, Lemna,* and *Spirodela* are omitted from this description, since there were no distributional records.

At Mermet, the American lotus (*Nelumbo lutea*) dominates the shallows and is slowly encroaching upon the remaining open water areas (Fig.

FIGURE 2. — Looking east along the north shore of Lake Glendale in July. Lowland vegetation includes the bald cypress (*Taxodium distichum*) and dense stands of the common cat-tail (*Typha latifolia*). The American lotus (*Nelumbo lutea*) and water-willow (*Dianthera americana*) grow in the shallow water areas. Photograph by James E. Ellis.

FIGURE 3. — August in Mermet Swamp. Acres of flowering, yellow lotus (*Nelumbo lutea*) cover the water surface. A black willow (*Salix nigra*) thicket is seen in the background. Photograph by Paul L. Fore.

3). Other rooted vegetation exhibiting aerial vegetative structures includes the arrowheads (*Sagittaria brevirostra* and *S. latifolia*), burhead (*Echinodorus cordifolius*), yellow pond-lily (*Nuphar advena*), and the common cat-tail (*Typha latifolia*). These amphibious plants not only characterize, but also help define, the term "swamp", that is to say, an advanced stage of lake succession.

A discussion of the varied aquatic habitats in southern Illinois is given by Mohlenbrock, Dillard, and Abney (1961). For aquatic floristic studies of Pine Hills Swamp (Union County), Devil's Kitchen Lake (Williamson County), Lake Murphysboro (Jackson County), and strip mine waters in southern Illinois, refer to Mohlenbrock (1959), Stookey, Fore, and Mohlenbrock (in press), Mohlenbrock, Et Al (in press), and Bell (1956), respectively.

Distributional Considerations

Some of the more surprising and rare finds made in the course of this study include *Heteranthera limosa* (second county record from Illinois), *Leersia virginica* var. *ovata* (new Illinois state record for the variety), *Cabomba caroliniana* (fourth state county record), and *Potamogeton crispus* (first station in southern Illinois). Other unusual and seldom collected aquatic and amphibious species from the southern third of Illinois include *Sagittaria graminea, Lemna perpusilla, Naias minor, N. guadalupensis, Juncus diffusissimus, Wolffia papulifera,* and *Myriophyllum pinnatum. Naias minor* is of particular interest, since it was first discovered in Illinois in 1963 in Lake Murphysboro (Fore and Mohlenbrock, in press). Subsequent investigations reveal that this species is fairly common and may occasionally dominate the submerged hydric community as demonstrated by its occurrence in Harrisburg North Reservoir (Saline County).

The distributions of aquatic vascular plants of Illinois are enumerated by Winterringer and Evers (1961) and by Jones and Fuller (1955) in an earlier publication. Subsequent taxonomic studies by Mohlenbrock and Drapalik (1962), by Fore and Mohlenbrock (in press), by DeFilipps (1964), and by Mohlenbrock (1963) are utilized wherever applicable. On the basis of the previously published reports, a total of 217 new county records (for southern Illinois) is reported, which includes 90 species, 58 genera, and 39 families.

Annotated Checklist of Aquatic Distributional Records

The specimens of this study are on deposit in the Southern Illinois University Herbarium (SIU). Fore and Stookey collected these aquatics during the summer of 1963; their names and the collection dates are omitted from this checklist to prevent repetition. Reference to specimens in the following text is by italicized numbers. The nomenclature conforms to Jones (1963). Distributional data apply primarily to southern Illinois; however, previously published county records are not always indicated.

Equisetaceae Rich.

Equisetum hyemale L. Tall scouring-rush is very common in moist situations.

County record. — JEFFERSON: Mt. Vernon City Reservoir, *759*.

Salviniaceae Reichenb.

Azolla mexicana Presl. Although somewhat rare, this species is now known from five locations in southern Illinois.
County record. — FRANKLIN: Plumfield Lake, N. of Plumfield, *675* and strip pit, 1 mi. W. of Zeigler, *674*.

Taxodiaceae Schimper

Taxodium distichum (L.) Rich. Bald cypresses are usually restricted to counties bordering the Mississippi, Ohio, and Wabash Rivers. This collection represents the northwest limit of its distribution in Illinois. However, the occurrence in Washington County may not represent natural dispersion, but rather establishment by man.
County record. — WASHINGTON: Nashville Reservoir, 1 mi. E. of Nashville, *635*.

Typhaceae J. St. Hil.

Typha angustifolia L. This finding represents the fourth station from the southern part of the state.
County record. — JACKSON: Lake Murphysboro, *504*.

Typha latifolia L. This distinctive emergent is abundant in the shallow waters and along the shorelines of most lakes and ponds.
County records. — EDWARDS: Shale strip pit, ½ mi. S. of Albion, *720*. GALLATIN: Pounds Hollow Lake, *581*. JEFFERSON: L. & N. Lake, in Mt. Vernon, *758*. MASSAC: Mermet Swamp, *558*. PERRY: Strip pits on Du Quoin Fair Grounds, *620*. WAYNE: Roadside ditch, 1 mi. N. of Wayne City, *734* and temporary roadside pond, 3 mi. S. of Wayne City, *769*. WHITE: Norris City Reservoir, *705*.

Naiadaceae Lindl.

Naias guadalupensis (Spreng.) Magn. Jackson and Williamson Counties represent the former records from southern Illinois (Winterringer and Evers, 1960). Subsequent investigations by Fore and Mohlenbrock (in press) and by the authors demonstrate that *N. guadalupensis* frequently inhabits (often in dense stands) older lakes and farm ponds in this part of the state.
County records. — FRANKLIN: Lake Benton, N. of Benton, *673*; West Frankfort City Lake, near Thompsonville, *672*; and Moses Lake, W. of Benton, *671*. HAMILTON: Jay's Lake, *692* and McLeansboro City Reservoir, *691*. JEFFERSON: Bluford Lake, *757* and Mt. Vernon Reservoir, *301*. JOHNSON: Vienna City Reservoir, *545*. PERRY: Du Quoin Reservoir, *304* and Lake Sallateeska, 5 mi. N. of Pinckneyville, *618*. POPE: Lake Glendale, *302*. RANDOLPH: Henderson's Lake, near Sparta, *651* and Coulterville Reservoir, *303*. ST. CLAIR: Forest Park Inn Lake, 1 mi. NW. of Tilden, *638*. WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *704*.

Naias minor All. All stations for the Eurasian naiad are located in southern Illinois, where it was previously reported from two lakes in Jackson and Williamson Counties (Stookey, Fore, and Mohlenbrock, in press). At present, *N. minor* exhibits a rather compact distribution, since it is known from eleven stations located in nine adjoining counties. Investigation of submerged habitats in northern Illinois may greatly extend its present range.
County records. — FRANKLIN: West Frankfort City Lake, ½ mi. S. of Thompsonville, *670* and West Frankfort Reservoir, near West Frankfort, *669*. GALLATIN: Pounds Hollow Lake, *580*. HAMILTON: McLeansboro Reservoir, *690* and Jay's Lake, *689*. JEFFERSON: Mt. Vernon Reservoir, *755*. JOHNSON: Vienna Reservoir, *544*. POPE: Lake Glendale, *564*. SALINE: Harrisburg North Reservoir, 1 mi. E. of Galatia, *588*.

Potamogetonaceae Engler

Potamogeton americanus C. & S. The distribution of this species is statewide; it is probably abundant in suitable waters in every Illinois county.
County records. — FRANKLIN: West Frankfort City Lake, *668*. PERRY: Pyatts strip pits, *617* and strip pit, Du Quoin State Fair Grounds, *615*. SALINE: Harrisburg North Reservoir, *587*. ST. CLAIR: Forest Park Inn Lake, 1 mi. NW. of Tilden, *637*. WASHINGTON: Washington County Conservation Lake, *634*.

Potamogeton crispus L. This is the first collection of this native of Europe from the southern half of the state.
County record. — EDWARDS: Limestone quarry pond, ½ mi. S. of Albion, *719*.

Potamogeton diversifolius Raf. This pi-

oneer aquatic inhabits most lakes in southern Illinois.
County records. — FRANKLIN: West Frankfort Reservoir, *667*. GALLATIN: Pounds Hollow Lake, *579*. HAMILTON: In creek, 2 mi. S. of Keene, *688* and Frey Lake, 1 mi. W. of Belle Prairie, *687*. MASSAC: Mermet Swamp, *557*. PERRY: Lake Sallateeska, 5 mi. N. of Pinckneyville, *614*. WAYNE: Roadside pond, 5 mi. E. of Fairfield, *733*. WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *705*.

Potamogeton foliosus Raf. Chiefly occurring in the northern part of the state, this species is now known from six southern counties.
County records. — JEFFERSON: Jaycee Lake, N. of Mt. Vernon, *754*. JOHNSON: Stone quarry, N. of Vienna, *543*. POPE: Lake Glendale, *563*. WASHINGTON: Washington County Conservation Lake, *633*.

Potamogeton pectinatus L. In addition to the previously reported stations in St. Clair and Wabash Counties, the Perry County collection represents the most southern range extension of this species in Illinois.
County record. — PERRY: Pinckneyville Reservoir, *613*.

Potamogeton pusillus L. This aquatic was thought to have a sparce distribution throughout southern Illinois, since it was previously recorded only from Wabash and St. Clair localities. The discovery of *P. pusillus* in Johnson County represents the southern limit of its Illinois distribution.
County records. — EDWARDS: Shale strip pit, ½ mi. S. of Albion, *718*. FRANKLIN: Lake Benton, N. of Benton, *666*. HAMILTON: Jay's Lake, *686*. JACKSON: Lake Murphysboro, *503*. JOHNSON: Fern Clyffe Lake, *443*. PERRY: Du Quoin Reservoir, *612*. WASHINGTON: Washington County Conservation Lake, *632*.

Alismaceae DC.

Alisma subcordatum Raf. This species is widely distributed throughout Illinois.
County records.—JEFFERSON: Mt. Vernon City Reservoir, *753;* L. & N. Lake, Mt. Vernon, *752*. PERRY: Du Quoin Reservoir, *611*. PULASKI: Cache River near Perks, *539*. SALINE: Harrisburg North Reservoir, *586*. WASHINGTON: Ashley City Reservoir, *631*. WAYNE: In creek, 2 mi. S. of Keene, *732*.

Echinodorus cordifolius (L.) Griseb. The collection from Big Lake in Gallatin County denotes the first discovery of this aquatic from a southeastern border county.
County records. — ALEXANDER: Horseshoe Lake, *531*. GALLATIN: Big Lake, 2 mi. NE. of Old Shawneetown, *578*. MASSAC: Mermet Swamp, *556*.

Sagittaria brevirostra Mack. & Bush. The collections from Massac, Pope, and Gallatin Counties are the first recorded stations from those counties adjacent to the Ohio River.
County records. — GALLATIN: Big Lake, 2 mi. NE. of Old Shawneetown, *577*. MASSAC: Mermet Swamp, 1 mi. SW. of Mermet, *555*. MONROE: Moredock Lake, N. of Valmeyer, *643*. PERRY: Du Quoin Reservoir, *610*. POPE: Lake Glendale, 2 mi. N. of Dixon Springs State Park, *562*. WAYNE: Roadside ditch, 1 mi. N. of Wayne City, *731*. WHITE: Roadside ditch, 3 mi. S. of Norris City, *702*.

Sagittaria calycinus Engelm. Only three stations (St. Clair, Jackson, and Alexander Counties) were previously listed for this arrowhead in southern Illinois.
County records. — FRANKLIN: West Frankfort City Lake, *665* and temporary farm pond, 3 mi. N. of Thompsonville, *664*. HAMILTON: Jay's Lake, SW. of McLeansboro, *685*. JEFFERSON: Bluford Lake, 2 mi. SE. of Bluford, *751*. PERRY: Pinckneyville Reservoir, *609*. PULASKI: Cache River bottoms, about 2 mi. S. of Perks, *538*. RANDOLPH: Coulterville Reservoir, near Coulterville, *647*. SALINE: Harrisburg North Reservoir, *585*. WABASH: Farm pond, 4 mi. W of Mt. Carmel, *707*. WASHINGTON: Nashville Reservoir, *630*.

Sagittaria graminea Michx. This is the first known station for this lowland species in the southeastern half of Illinois.
County record. — POPE: Lake Glendale, *561*.

Sagittaria latifolia Willd. The common arrowhead inhabits the margins of lakes, farm ponds, and ditches.
County records. — MASSAC: Mermet Swamp, *554*. MONROE: Gilmore Lake, 3 mi. S. of Columbia, *642*. POPE: Lake Glendale, *560*. RANDOLPH: Coulterville Reservoir, *648*.

Hydrocharitaceae Aschers.

Limnobium spongia (Bosc) Steud. This floating species was previously described from swampy and stagnant

habitats in Union and Alexander Counties (Mohlenbrock, 1959). Southern Illinois is one of the northern range limits of this species, which is primarily restricted to the southeastern United States (Fernald, 1950).
County records. — MASSAC: Mermet Swamp near Mermet, *553*. PULASKI: Cache River bottoms near Perks, *537*.

Gramineae Juss.

Leersia virginica Willd. var. *ovata* (Poir.) Fern. This collection is a state record for variety *ovata*, but it falls within its reported range from Maine to Minnesota, south to Texas and Georgia (Fernald, 1950).
County record. — WHITE: Roadside ditch, 3 mi. S. of Norris City, *701*.
Uniola latifolia Michx. This species is quite common in the southern half of the state.
County records. — HAMILTON: Roadside ditch, 3 mi. N. of McLeansboro, *684*. WAYNE: Roadside ditch, 3 mi. S. of Wayne City, *700*.

Cyperaceae J. St. Hil.

Bulbostylis capillaris (L.) C. B. Clarke. The only species of *Bulbostylis* in Illinois has an even distribution (Mohlenbrock, 1963).
County record.—PERRY: Pinckneyville Reservoir, *607*.
Carex frankii Kunth. Common.
County record. — FRANKLIN: Strip pit, 1 mi. W. of Zeigler, *663*.
Carex grayii Carey. Wide distribution.
County record. — WHITE: Roadside ditch, 3 mi. S. of Norris City, *699*.
Carex lupuliformis Sartw. This species has a sporadic distribution throughout Illinois.
County record. — FRANKLIN: Railroad embankment, 1 mi. N. of Zeigler, *662*.
Carex muhlenbergii Schk. Very common.
County record. — WASHINGTON: Ashley City Reservoir, *629*.
Carex normalis Mack. Previously, only four southern Illinois stations were listed as records.
County record. — FRANKLIN: Strip pit, 1 mi. W. of Zeigler, *661*.
Cyperus aristatus Rottb. This species commonly inhabits moist stream banks.
County record. — WABASH: Wabash River, shoreline, at Mt. Carmel, *706*.
Cyperus erythrorhizos Muhl. Common.
County record. — PERRY: Du Quoin Reservoir, *606*.
Eleocharis acicularis (L.) Roem. and Schultes. Mohlenbrock and Drapalik (1962) record this species from five counties in southern Illinois.
County records. — JEFFERSON: Jaycee Lake, near Mt. Vernon, *750*. MONROE: Gilmore Lake, 3 mi. S. of Columbia, *641*. PERRY: Du Quoin Reservoir, *605*. POPE: Lake Glendale, moist shoreline, *559*. WAYNE: Fairfield Reservoir, *730* and roadside ditch, 3 mi. S. of Wayne City, *729*. WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *698*.
Eleocharis erythropoda Steud. Localities in Wabash and Massac Counties represent the two previously known distributional records from southern Illinois.
County records. — HARDIN: On the banks of Ohio River at Elizabethtown, *659*. JACKSON: Lake Murphysboro, along shoreline, *502*. WASHINGTON: Nashville Reservoir, *628*.
Eleocharis obtusa (Willd.) Schultes var. *obtusa* (Roth) Drap. and Mohl. Jefferson County is now the only uncollected county in southern Illinois for this common species (Mohlenbrock and Drapalik, 1962).
County records. — RANDOLPH: Coulterville Reservoir, *647*. SALINE: Harrisburg North Reservoir, 2 mi. E. of Galatia, *584*. WASHINGTON: Ashley City Reservoir, *627*.
Fimbristylis autumnalis (L.) Roem. and Schultes. This amphibious species is commonly found around the moist shorelines of lakes and of streams.
County records. — EDWARDS: Moose Lake, 3 mi. N. of Albion, *717*. HAMILTON: Temporary roadside ditch, 3 mi. N. of McLeansboro, *683* and Frey Lake, 1 mi. W. of Belle Prairie, *682*. PERRY: Pinckneyville Reservoir, *604*. RANDOLPH: Sparta Country Club Lake, *646*.
Scirpus cyperinus (L.) Kunth. Common.
County record. — HAMILTON: Temporary roadside ditch, 3 mi. N. of Mcleansboro, *681*.

Lemnaceae Dumort.

Lemna minor L. This floating aquatic inhabits the shallow littoral of many lakes and swamps.
County records. — GALLATIN: Around the shore of Big Lake, *575*. JEFFERSON: L. & N. Lake, Mt. Vernon, *747* and Bluford Lake, *746*. PULASKI: Cache River bottoms, near Perks, swampy area, *536*. SALINE: Floating among dense stands of *Typha*, Harrisburg North Reservoir, *583*.
Lemna perpusilla Torr. This rare duckweed has a sporadic distribution

throughout Illinois. These two collections represent the third and fourth county records from southern Illinois.
County records. — MONROE: Moredock Lake, near Valmeyer, *640*. WAYNE: In roadside ditch, 1 mi. E. of Fairfield, *728*.

Spirodela polyrhiza (L.) Schleid. The Gallatin location marks the first station from a southeastern border county. However, this species is fairly common and is recorded from most southwestern counties.
County records. — FRANKLIN: Strip pit, 1 mi. W. of Zeigler, *660*. GALLATIN: Big Lake, N. of Shawneetown, *576*. JEFFERSON: Bluford Lake, 2 mi. SE. of Bluford, *749* and L. & N. Lake in Mt. Vernon, *748*.

Wolffia papulifera C. H. Thompson. This tiny aquatic was listed previously from Union and Alexander Counties. Franklin and Monroe localities represent the eighth and ninth collections from Illinois.
County records. — FRANKLIN: Plumfield Lake, *659*. MONROE: Steppig Lake, near Columbia, *639*.

Pontederiaceae Dumort.

Heteranthera limosa (Sw.) Willd. St. Clair County represented the only county record for this rare species in Illinois, where it was collected near East St. Louis in 1877, 1896, and 1947 (Jones and Fuller, 1955). The finding of this native of tropical America in Hardin County is quite surprising, because of its disjunct state distribution. However, mud plantain does exist within its previously reported United States range from Kentucky to Minnesota, south to New Mexico and Florida.
County record. — HARDIN: Temporary farm pond, Hywy. Junc. 146 and 1, 2 mi. N. of Cave-In-Rock, *568*.

Juncaceae Vent.

Juncus acuminatus Michx. Widespread distribution throughout Illinois; fairly common.
County records. — EDWARDS: Along shoreline of Moose Lake, 3 mi. N. of Albion, *716*. RANDOLPH: Coulterville Reservoir, *645*.

Juncus diffusissimus Buckl. This uncommon species is restricted to the southern third of the state. Prior to this finding, it was collected in 1952 in Lawrence (County immediately north of Wabash) and in 1953 and 1956 from two stations in Jackson County (DeFilipps, 1964).
County record. — JEFFERSON: Moist soil around Mt. Vernon City Reservoir, *745*.

Juncus nodatus Coville. Winterringer and Evers (1960) list this species from only five other localities in southern Illinois.
County records. — FRANKLIN: Benton Lake, *658*. JEFFERSON: Jaycee Lake, N. of Mt. Vernon, *744*. WAYNE: Fairfield Reservoir, *727*.

Saururaceae Lindl.

Saururus cernuus L. Lizard's tail is locally abundant along moist shorelines and roadside ditches and has a wide range distribution.
County records. — JEFFERSON: Roadside ditch, 4 mi. S. of Mt. Vernon along Route 37, *743*. WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *697*.

Salicaceae Lindl.

Populus deltoides Marsh. This lowland tree is found throughout the state.
County record. — JEFFERSON: Jaycee Lake, N. of Mt. Vernon, *742*.

Salix caroliniana Michx. Being restricted to the lower half of the state, Jones and Fuller (1955) record this willow only from St. Clair and Madison (immediately north of St. Clair) Counties.
County record. — JACKSON: Lake Murphysboro, *501*.

Salix nigra Marsh. The black willow is now recorded in southern Illinois from all counties, except Hardin.
County record. — EDWARDS: Shale strip pit, ½ mi. S. of Albion, *715*.

Betulaceae Agardh

Betula nigra L. River birch is restricted chiefly to the western and southern parts of Illinois.
County record. — GALLATIN: Big Lake, 2 mi. NE. of Old Shawneetown, *574*.

Aristolochiaceae Blume

Aristolochia serpentaria L. This rare species, Virginia snakeroot, is primarily restricted to the southern half of Illinois.
County record. — PULASKI: Cache River bottom, near Perks, *535*.

Polygonaceae Lindl.

Polygonum coccineum Muhl. This scarlet-colored smartweed is very common and widely dispersed.

County records. — GALLATIN: Pounds Hollow Lake, *573*. MASSAC: Mermet Swamp, 1 mi. SW. of Mermet, *552*.

Polygonum hydropiperoides Michx. This species commonly grows either in wet soil or in water.
County record. — PERRY: Around strip pits on Du Quoin Fair Grounds, *603*.

Polygonum lapathifolium L. This species is widely distributed throughout Illinois.
County record. — JOHNSON: Along shoreline of Vienna Reservoir, *543*.

Polygonum pennsylvanicum L. Abundant.
County records. — PERRY: Pinckneyville City Reservoir, *602*. WAYNE: Roadside ditch, 3 mi. S. of Wayne City, *726*.

Polygonum persicaria L. Lady's thumb is commonly found growing in wet roadside ditches.
County record. — WHITE: Roadside ditch, 3 mi. S. of Norris City, *696*.

Polygonum sagittatum L. This uncommon species is now known from nine southern Illinois counties.
County records. — EDWARDS: Moose Lake, *714*. JEFFERSON: Bluford Lake, *741* and L. & N. Lake in Mt. Vernon, *740*.

Rumex verticillatus L. Prefers moist conditions; common.
County record. — WAYNE: Moist creek bed, 2 mi. S. of Keene, *725*.

Cabombaceae A. Gray

Brasenia schreberi Gmel. Only Wabash, Franklin, and Union localities were previously listed as distributional records; rare.
County records. — MASSAC: Mermet Swamp, *551*. WILLIAMSON: Madison Pond, near Blairsville, *594*.

Cabomba caroliniana A. Gray. Winterringer and Evers (1960) listed this submerged aquatic from a single Illinois station in Moses Lake, Franklin County. However, fanwort was collected in 1952 from Union County [Wolf Lake, near bridge to powder plant, *Bailey & Swayne 2555* (SIU)] and in 1961 from Williamson County [Mine Pond 12 near Cambria, *Dillard s.n.* (SIU)]. The station in Mermet Swamp represents the fourth Illinois county record for this unusual species.
County record. — MASSAC: Mermet Swamp, 1 mi. SW. of Mermet, *550*.

Nelumbonaceae Lindl.

Nelumbo lutea (Willd.) Pers. The American lotus is widespread and commonly found in the shallow waters of most of the older aquatc habitats in southern Illinois.
County records. — EDWARDS: Moose Lake, 3½ mi. N. of Albion, *713*. FRANKLIN: West Frankfort City Lake, *657*. JOHNSON: Roadside ditch, ½ mi. E. of Vienna along Hywy. 146, *540*. MASSAC: Mermet Swamp, *549*.

Nymphaeaceae DC.

Nuphar advena Ait. This emergent species is usually restricted to sheltered lake shores and to slow moving streams; common.
County records. — FRANKLIN: Strip pit, 1 mi. W. of Zeigler, *556*. HAMILTON: Frey Lake, 1 mi. W. of Belle Prairie, *680*. HARDIN: Temporary farm pond, 1 mi. W. of Hywy. Junc. 146 and 1, *567*. MASSAC: Mermet Swamp, *548*. WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *593*.

Ceratophyllaceae A. Gray

Ceratophyllum demersum L. Coontail is primarily restricted to the western counties of southern Illinois; locally abundant.
County records. — JEFFERSON: Mt. Vernon City Reservoir, *739*. PERRY: Du Quoin Fair Grounds, strip pits, *601*. PULASKI: Cache River, S. of Perks, *534*.

Cruciferae B. Juss.

Rorippa sinuata (Nutt.) Hitchc. In southern Illinois, this species usually inhabits moist river banks; sparce distribution.
County record. — HARDIN: Along the shore of the Ohio River at Elizabethtown, *566*.

Crassulaceae DC.

Penthorum sedoides L. Ditch stonecrop is now known from all twenty-three southern counties, except Randolph.
County records. — EDWARDS: Moose Lake, 3½ mi. N. of Albion, *712*. PERRY: Du Quoin Reservoir, *600*. UNION: LaRue Swamp, ¼ mi. N. of Pine Hills Field Station, *505*.

Euphorbiaceae J. St. Hil.

Chamaesyce maculata (L.) Small. Gallatin County is the only location in southern Illinois in which this common lowland plant is not now listed as a distributional record.
County record. — WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *592*.

Hypericaceae Lindl.

Hypericum mutilum L. Fairly common in the southern half of the state.
County record. — WAYNE: Roadside ditch, 1 mi. N. of Wayne City, *724*.

Lythraceae Lindl.

Ammannia coccinea Rottb. This species is now listed as occurring in every southern Illinois county.
County records. — FRANKLIN: Moses Lake, *655* and Lake Benton, *654*. JEFFERSON: Mt. Vernon Reservoir, *738*. SALINE: Harrisburg North Reservoir, *582*. WAYNE: Roadside ditch, 1 mi. N. of Wayne City, *723*.

Rotala ramosior (L.) Koehne. Toothcup is widely distributed throughout the southern part of Illinois.
County records. — EDWARDS: Moose Lake, 3½ mi. N. of Albion, *711*. HAMILTON: Roadside ditch, 3 mi. N. of McLeansboro, *679* and McLeansboro Reservoir, *678*. JEFFERSON: Jaycee Lake, N. of Mt. Vernon, *737*. PERRY: Pinckneyville Reservoir, *599*. RANDOLPH: Coulterville Reservoir, *644*. WAYNE: Fairfield Reservoir, *722*.

Onagraceae Dumort.

Jussiaca decurrens (Walt.) DC. This species is apparently restricted to southern Illinois where is is now recorded from eight counties.
County record. — GALLATIN: Pounds Hollow Lake, *572*.

Jussiaea diffusa Forsk. Water primrose commonly inhabits lakes and farm ponds in this half of Illinois.
County records. — ST. CLAIR: Forest Park Inn Lake, 1 mi. NW. of Tilden, *636*. WASHINGTON: Washington County Conservation Lake, *626*. WHITE: Sandy Run Lake, 4 mi. S. of Norris City, *695*. WILLIAMSON: Devil's Kitchen Lake, *591*.

Ludwigia alternifolia L. Wide distribution; extremely common.
County records. — ALEXANDER: Temporary pond, 2 mi. W. of Tamms, *530*. GALLATIN: Pounds Hollow Lake, *571*. WASHINGTON: Nashville City Reservoir, *625*.

Haloracaceae Horan.

Myriophyllum pinnatum (Walt.) BSP. The main distribution of this aquatic is in the western half of Illinois. Winterringer and Evers (1960) list this species only from St. Clair and Randolph stations in southern Illinois; very rare.
County records. — PERRY: Pyatts strip pits, *598*. WILLIAMSON: Pond, 2 mi. W. of Johnson City, *590*.

Primulaceae Vent.

Lysimachia nummularia L. Moneywort is commonly found around the damp shorelines of lakes and ponds.
County records. — JEFFERSON: L. & N. Lake in Mt. Vernon, *736*. WASHINGTON: Ashley City Reservoir, *624*.

Asclepiadaceae Lindl.

Asclepias incarnata L. Swamp milkweed inhabits moist soils; wide Illinois distribution.
County record. — ALEXANDER: In moist shoreline soil around Horseshoe Lake, *506*.

Convolvulaceae Vent.

Cuscuta cuspidata Engelm. The Perry station represents the sixth collection from southern Illinois.
County record. — PERRY: Du Quoin Reservoir, *597*.

Labiatae Juss.

Lycopus americanus Muhl. This common herb is abundant in all parts of the state; it has now been collected from every southern Illinois county.
County records. — HAMILTON: McLeansboro Reservoir, *769*. JOHNSON: Swamp along Hywy. 146, ½ mi. E. of Grantsburg, *786*. PERRY: Strip pits located on Du Quoin Fair Grounds, *773*.

Lycopus virginicus L. This species is sparsely distributed in southern Illinois.
County records. — FRANKLIN: Lake Benton, along moist shoreline, *653*. JEFFERSON: L. & N. Lake in Mt. Vernon, *735*. WHITE: Sandy Run Lake, *694*.

Scrophulariaceae Lindl.

Bacopa rotundifolia (Michx.) Wettst. This species is not uncommon in the southern tip of the state, but it becomes increasingly sporadic in occurrence to the north.
County records. — PULASKI: Moist roadside ditch, 2 mi. N. of Albion, *533*. WILLIAMSON: Devil's Kitchen Lake, *589*.

Gerardia gattingeri Small. This species has a scattered distribution in the

northern two-thirds of Illinois, but it is more frequent in occurrence in the southern end of the state.
County records. — HAMILTON: Temporary roadside ditch, 3 mi. N. of McLeansboro, *677*. PERRY: Lake Sallateeska, N. of Pinckneyville, *596*. PULASKI: Cache River, near Perks, *532*.

Gratiola neglecta Torr. This species, which inhabits the moist margins of ponds and lakes, has now been discovered in all but three counties in southern Illinois.
County records. — GALLATIN: Pounds Hollow Lake, *768*. WASHINGTON: Nashville City Reservoir, *623*.

Acanthaceae J. St. Hil.

Ruellia pedunculata Torr. The range of this coastal species is restricted to the southern third of the state, which represents the northern limit of its southern distribution (Fernald, 1950).
County record. — WASHINGTON: Washington County Conservation Lake, *622*.

Lentibulariaceae Lindl.

Utricularia gibba L. In Illinois, this bladderwort is confined to the western and southern borders of southern Illinois and to the extreme northeast corner of the state. The apparent gaps in range throughout eastern and central portions of the state probably are attributable to the lack of suitable semi-stagnant, aquatic habitats.
County record. — MASSAC: Mermet Swamp, 1 mi. SW. of Mermet, *547*.

Utricularia vulgaris L. This submerged aquatic has a sporadic distribution in Illinois and has previously been reported from only two southern stations located in St. Clair and Union Counties.
County record. — MASSAC: Mermet Swamp, 1 mi. SW. of Mermet, *546*.

Bignoniaceae Pers.

Campsis radicans (L.) Seem. Collections of the trumpet-creeper are now recorded from twenty of the twenty-three southern Illinois counties.
County record. — PERRY: Pickneyville Reservoir, *595*.

Rubiaceae B. Juss.

Cephalanthus occidentalis L. Buttonbush is quite common around the shores of most aquatic habitats. It is now known from all twenty-three of the southern counties.
County record.—GALLATIN: Big Lake, 2 mi. NE. of Old Shawneetown, *570*.

Compositae P. F. Gmel.

Bidens comosa (A. Gray) Wieg. Beggarticks inhabit moist lowlands throughout the state; it is now known from nine southern Illinois counties.
County record. — WAYNE: Fairfield Reservoir, *721*.

Bidens frondosa L. Widespread Illinois distribution.
County record. — EDWARDS: Moose Lake, 3½ mi. N. of Albion, *709* and shale strip pit, ½ mi. S. of Albion, *708*.

Bidens polylepis Blake. This species occurs throughout Illinois, but it appears to be most abundant in the southern fourth of the state.
County record. — WASHINGTON: Nashville Reservoir, *621*.

Bidens vulgata Greene. Sporadic distribution throughout southern Illinois; not common.
County record. — EDWARDS: Moose Lake, 3½ mi. N. of Albion, *710*.

Mikania scandens (L.) Willd. Climbing hempweed is known to extend into Illinois as far north as Lawrence County (immediately north of Wabash County). The Franklin County record represents the sixth Illinois station.
County record. — FRANKLIN: Strip pit, 1 mi. W. of Zeigler, *652*.

Xanthium commune Britt. Widespread distribution in Illinois.
County records. — HAMILTON: McLeansboro Reservoir, *676*. WHITE: Wabash River at Grayville, *693*.

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THE ASIATIC CLAM (*CORBICULA*) IN ILLINOIS

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ABSTRACT. — Specimens of the introduced Asiatic clam (*Corbicula*) were obtained at 18 collection stations located in the Ohio, lower Wabash and Mississippi rivers bordering southern and eastern Illinois. This clam has now (1964) become established throughout the lower Ohio River and has ascended the Wabash River as far as White County, Illinois. No specimens were found in the Mississippi River above Cairo. Rapid dispersion and population growth of this introduced mollusk in Illinois waters have occurred within the past four or five years.

The introduced Asiatic clam was first observed in the United States in 1938 in California (Dundee and Dundee, 1958); between 1938 and 1963 this mollusk had spread to at least five other western states. Sinclair and Ingram (1961) reported *Corbicula* from the Tennessee River (Hardin County, Tennessee), the first occurrence of the Asiatic clam east of the Mississippi River. Since their report (op. cit.), this clam has also been recorded in eastern United States from Florida (Heard, 1964), Louisiana (Dundee and Harman, 1963), Alabama (Hubricht, 1963), Ohio (Keup, Horning and Ingram, 1963), West Virginia (Thomas and Mackenthun, 1964), Kentucky (Sinclair and Isom, 1961) and Illinois (Fechtner, 1962). The Kentucky and Illinois records are based on specimens of *Corbicula* taken from the Ohio River just east of Metropolis on the Illinois side and at the Shawnee Steam Plant, about two miles down river from Metropolis on the Kentucky side. Sinclair and Isom (1963) state that "All specimens examined from the Ohio River Basin belong to one species based on sexuality and life history, and are placed in the synonomy of *C. manilensis* together with *C. leana, C. javanica,* and *C. vicina.*"

The rapid dispersion and population growth of this clam are not fully understood. Possible means of dispersal such as their inclusion in sand and gravel dredged from one area and deposited in another (for example, by barge), accidental transportation by water birds (ducks swallowing small clams and passing an occasional individual through the digestive tract unharmed), and transporting and eventual discarding of clams by tourists, fishermen (using them as bait) or aquarium hobbyists have been suggested by Ingram, Keup and Henderson (1964) and others. It is quite possible that mollusk-feeding fish such as the freshwater drum (*Aplodinotus grunniens*) may be an important factor in the dispersal of this clam within a given river system. Sinclair and Ingram (1961) stated that "One can only speculate as to the mode of transportation of this native of Asia; however, a likely theory would first incriminate the dumping of aquaria and fish bowls that contained introduced 'aquaria rarities.'"

Desrciption of *CORBICULA*

The Asiatic clam is a bivalve mollusk (Fig. 1) belonging to the Class Pelecypoda, Order Heterodonta and Family Corbiculidae. Sinclair and Isom (1963) report the largest Tennessee River forms taken were 43 mm in length, although *Corbicula* in Western United States measured 55 mm and native forms from Formosa and China, 83 mm. There is considerable variation in the general shape of the adult shell and there occurs a change in shape of the individual clam from the juvenile to the adult stage. Sinclair and Isom (1961) describe the shell as ovate (young) to trigonal (mature) in shape, inflated at the umbones, heavy, sculptured with concentric rings and covered with a lustrous yellow-green periostracum. There are three cardinal teeth in each valve, two lateral teeth on each side in the right valve and one on each side in the left valve. Umbones of typical mature individuals are eroded.

Immature clams (1 mm or less in length) are cream colored and without pattern; by the time individuals reach 5 mm, shells take on the polished tan periostracum of the adult and by 8 mm the periostracum becomes olive in color and highly polished (Sinclair and Isom, 1961). Mature shells gradually darken from a

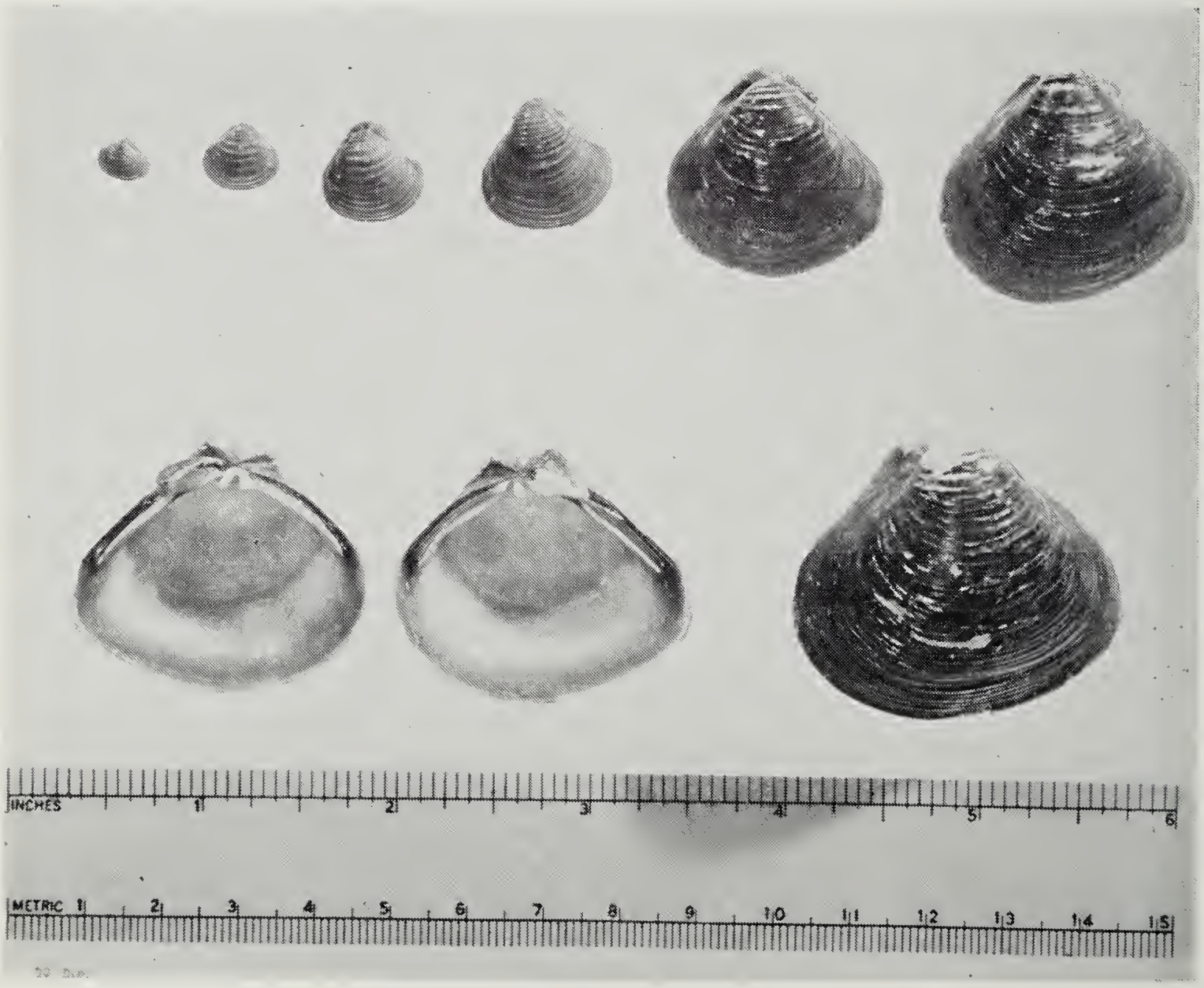

Figure 1. — Specimens of the Asiatic clam (*Corbicula*) from the Ohio River, Illinois.

brownish black to jet black. Very young specimens possess a characteristic dark stripe on the anterior central part of the valves and more narrow, less distinct stripes on the posterior margins. The inner margins of the shell are a deep purple color while the entire inner surface of adults is whitish or a very light purple.

Sinclair and Isom (1961) state that *Corbicula* from the Tennessee River reaches sexual maturity during the first year at a length of 6.5 mm, and that the spawning season extends from at least July to November. Fertilized eggs of the clam develop in the inner demibranchs of the adult and the microscopic planktotrophic larvae are released by the thousands. Unlike most fresh-water naiads which pass through a stage of parasitic (glochidia) development on the gills or fins of fish, the veliger larvae of *Corbicula* begin a free-living existence on the bottom soon after being released into the water from the adult. During this study, *Corbicula* reached its greatest size and local abundance (Ohio River at Old Shawneetown) on a substratum of predominantly sand mixed with, or overlaying, mud in 1 to 2 feet of water.

CORBICULA IN ILLINOIS

During an August, 1964 field trip made by the author for the purpose of collecting fresh-water mussels in the lower Wabash River (White County, Illinois), two old valves of the Asiatic clam were found in a section of that river referred to as "little chains." These shells were sent to Ralph M. Sinclair, Principal Biologist, Stream Pollution Control, Department of Public Health, Nashville, Tennessee, who identified them as *Corbicula* cf. *manillensis*. I would like to express my sincere appreciation to Mr. Sinclair for this determination, for comparative material from the Tennessee River system and for his many helpful suggestions.

Keup, Horning and Ingram (1963) state that, based on a study by Jackson and Wise, "Asiatic clams were not found in benthic samples collected as late as January, 1960, from the Ohio River, from Pittsburgh, Pennsylvania, downstream to Mound City, Illinois." Since the only published record (Fechtner, 1962) for the occurrence of the Asiatic clam in Illinois was based on eleven recently dead specimens found in 6 inches of water east of Metropolis (Ohio River, Massac County), the recovery of *Corbicula* from the lower Wabash River suggested a possible rapid dispersal of this clam in Illinois waters during the last two or three years.

In order to determine the range extension of *Corbicula* in the major rivers bordering southern and eastern Illinois, collection stations (Mississippi River, 4; Ohio River, 8; Wabash River, 5) were established (Fig. 2) and shorelines varying from several hundred yards to 1½ miles were examined for the presence of this clam. A bottom sampler, consisting of a triangular-shaped, brass screened "basket" (1/16 inch mesh), 10 inches wide at the base, 17 inches long and covered with a hinged, wire (1 x 2 inch square) lid was used to remove and sift the substratum. The "basket" was welded to a shovel handle and this tool proved extremely

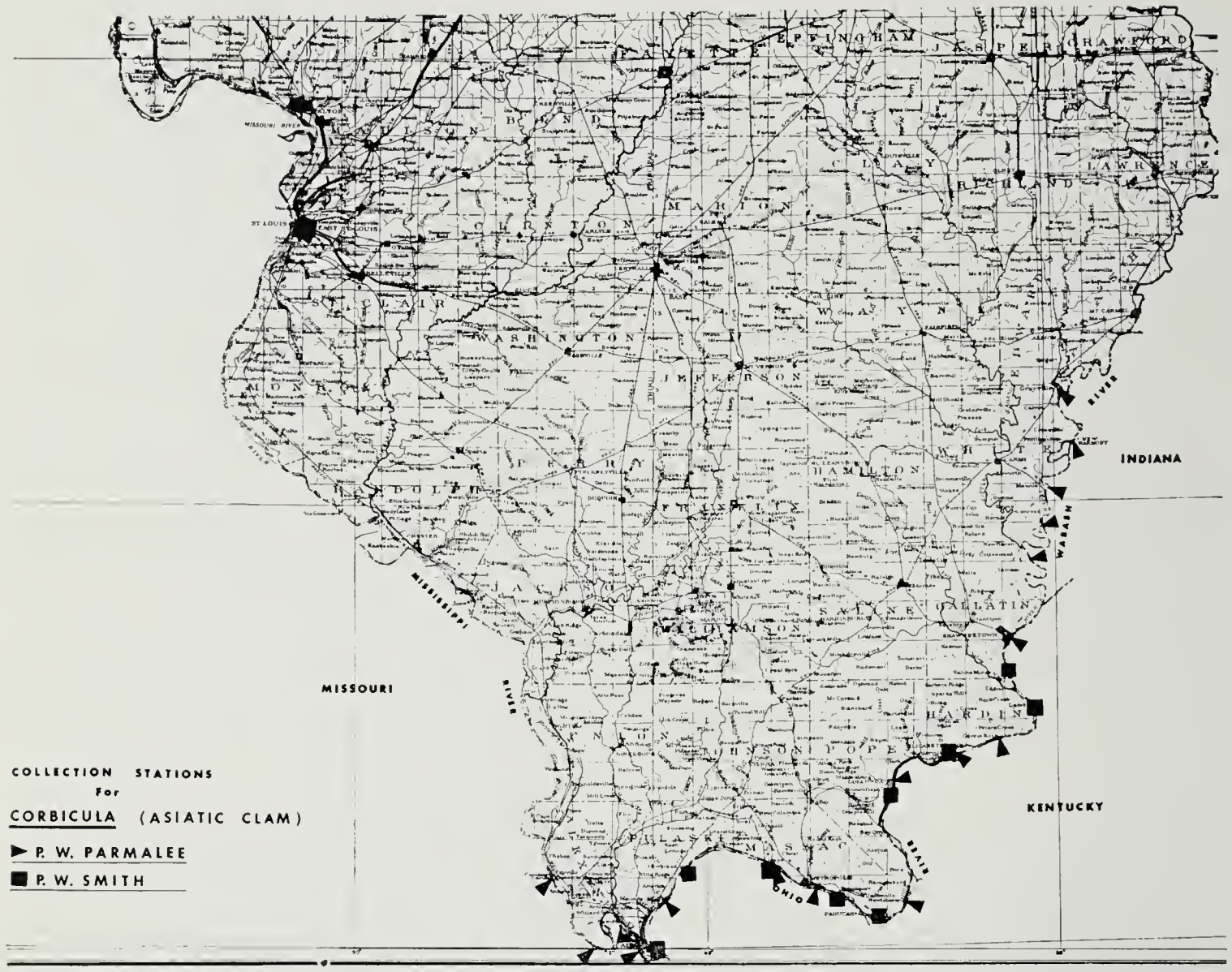

Figure 2. — Collection Stations Examined for the Presence of *Corbicula*, August and September, 1964.

efficient in obtaining living specimens.

This survey was undertaken on September 8, 9, and 10, 1964. In addition to the collection stations visited by the author (triangular symbols), *Corbicula* was obtained at eight other localities (square symbols, Fig. 2) on the Ohio River by personnel from the Illinois Natural History Survey and the Illinois Department of Conservation for Dr. Philip W. Smith. Sample collections of the Asiatic clam were saved for the author by Dr. Smith and his associates during their fish survey work, also on the above mentioned dates, and I would like to express my gratitude for their records.

Live specimens of *Corbicula* were taken at all stations on the Ohio River, thus establishing this introduced clam as an inhabitant throughout the entire length of the Ohio River bordering Illinois. Specimens taken on the Kentucky side of the river (confluence of the Ohio and Mississippi rivers at Cairo, and opposite Olmsted and Joppa, Illinois) by Philip W. Smith and his associates also suggest complete establishment of *Corbicula* along both shores. Of the 15 stations on the Ohio River, greatest population densities of the Asiatic clam were found at Mound City (Pulaski County), Ft. Massac State Park (Massac County) and at Old Shawneetown (Gallatin County).

The largest numbers (for unit of area) of adult *Corbicula* were encountered at Old Shawneetown. The animals were living in one to two feet of water on a substrate of sand and mud. Houseboats belonging to commercial fishermen were anchored at this locality and the waters around these boats were foul from the fish offal that was continually being thrown overboard. Such conditions probably favor the development of phytoplankton, the principal food of this clam, and it appeared that a larger number of individuals were attaining adult size (30 mm) within that local population.

Substrata at the other Ohio River stations varied from nearly pure sand to hardened clay and mud (Fort Defiance State Park at Cairo). Bottom conditions of the latter type are unfavorable for the establishment of *Corbicula* and clams were rare or absent in such habitats. The river was at low stage during this investigation and the greatest concentration of local Asiatic clam populations occurred in varying depths from six inches to two feet.

No specimens of *Corbicula* were encountered in the Mississippi River on the Illinois side at the four stations examined (Fig. 2). However, three dead valves (pairs) and one live immature specimen were found almost directly below the Illinois-Missouri bridge on the Missouri side of the river. Specimens obtained by Philip W. Smith and his associates along a sand bar in Kentucky directly across the Ohio River from Cairo (Ft. Defiance) and the few shells taken by the author in the Mississippi River on the Missouri shore establish the range of *Corbicula* south to the confluence of these rivers. Judging from its known fast rate of dispersal, the Asiatic clam can soon be expected to ascend the Mississippi River into local areas of suitable habitat.

Living specimens of the Asiatic clam were taken at two stations on the lower Wabash River. At the first station, a sand bar extending 1-1½ miles along the Illinois shore approximately 2 miles S.E. of New Haven, Gallatin County, numerous immatures and young adults were encountered in the shallow water, moist sand and pools left by the receding river. The largest specimen measured only 19 mm and this population was sparse compared with the dense local concentrations encountered at certain localities in the Ohio River. Shells were a polished olive-yellow in color and only the three largest specimens (17-19 mm) showed a beginning of the trigonal shape of the adult. These largest clams were probably 2-3 years of age, judging from age and length data given by Sinclair and Isom (1961). Using these same age criteria data, the Ohio River populations had been established for at least 3 years.

The second Wabash River station, 2 miles S. E. of Rising Sun, White County, is known locally as "little chains." Large broken slabs of limestone form the bank along the Illinois side for about ¾ of a mile and compose the river bed nearly to the Indiana side. This produces a rapids with swift current; the substratum consists of these large flat rock slabs, stones and coarse gravel mixed with some sand and mud. Only 3 old valves and one living young adult (2 years of age?) were found. Collect-

ing was difficult because of the type of substrate and it is possible a population of *Corbicula* is more extensive at this point than the few shells recovered would suggest.

However, no specimens of this clam, living or dead, were encountered in over a mile of sand beach at the next station (2 miles S. E. of Maunie) approximately 5 miles north of "little chains." Examination of sand bars at New Harmony, Indiana, and at Grayville, Illinois, failed to produce *Corbicula*. The confluence of the Ohio and Wabash rivers is about 12 river miles below the first Wabash River station where this clam was collected. It would appear that range extension of the Asiatic clam in Illinois occurs more rapidly in a downstream direction. Possibly populations of the Asiatic clam became established in the lower Ohio River as a result of individuals being carried downstream by current. Natural ascent of a river for a mollusk like the Asiatic clam would be expected to be slower than descent. Relatively sparse (young?) populations of *Corbicula* in the lower Wabash River versus a dense (old) populations in the Ohio River at Old Shawneetown, localities approximately equal distance from the confluence of these rivers, would suggest an upstream source (for example the Cincinnati area: Keup, Horning and Ingram, 1963) for the Ohio River populations in Illinois. Possibly severe winter conditions may limit the northward spread of this clam or its abundance in northern latitudes, as may have been the case in Ohio (Horning and Keup, 1964).

What impact the Asiatic clam will have on the biology of Illinois waters and related fauna, or on certain industries associated with the major waterways, remains to be seen. The nuisance aspects of *Corbicula* have been discussed by Sinclair and Isom (1961) and Sinclair (1963) — the clogging of intake and cooling water pipes at various steam plants and the contamination of sand and gravel deposits. On the beneficial side, this clam may prove to be of value as a food for numerous species of economically important fish and waterfowl.

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A NEW SPECIES OF *ELEUTHERODACTYLUS* FROM EASTERN MEXICO

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ABSTRACT. — A new species of the *Eleutherodactylus rhodopis*-group (Salientia: Leptodactylidae) is described from Volcan San Martin Pajapan, Veracruz, Mexico. The frog appears most closely related to *E. macdougalli* of Oaxaca and Chiapas, Mexico. It is presumed endemic to the Los Tuxtlas Range of Veracruz, Mexico.

The most poorly understood complex of the genus *Eleutherodactylus* (Salientia: Leptodactylidae) is the *E. rhodopis* group, heretofore represented by eight Mexican species. This group is characterized by: toe and finger tips not bulbous or expanded, no extensive webbing between toes, vomerine teeth present, inguinal gland lacking, and no postocular dermal folds. Six species occur in the Los Tuxtlas Range of Veracruz, Mexico, and two of the six are known only from Volcan San Martin (Shannon and Werler, 1955:370 and 375). The present paper describes a third presumed endemic species of the *E. rhodopis* group from Volcan San Martin. This new form is based on a single specimen in the University of Illinois Museum of Natural History (UIMNH).

Eleutherodactylus werleri, new species

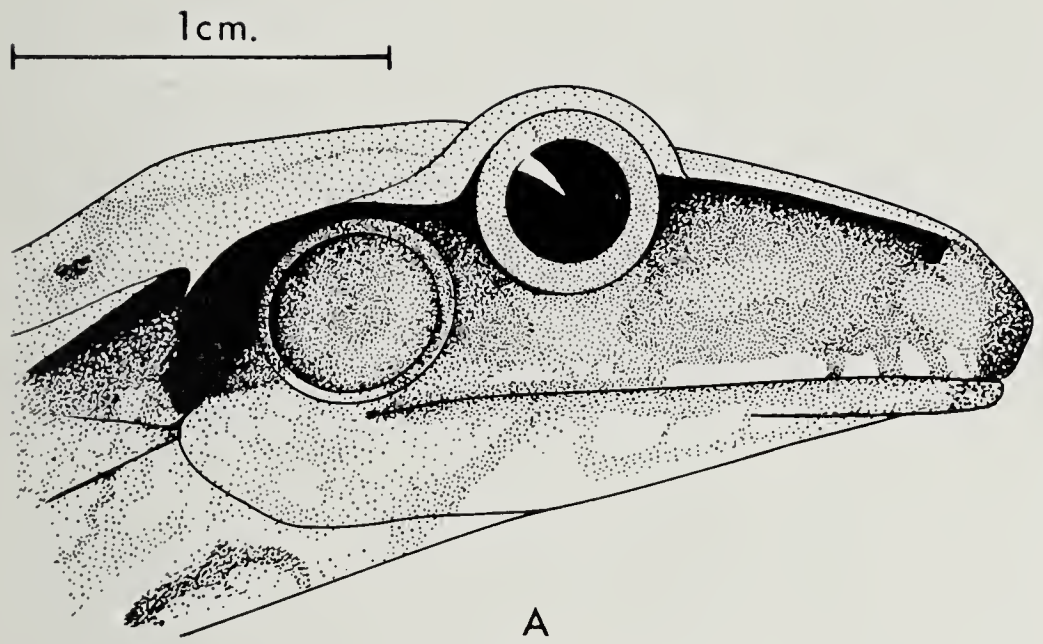
Holotype. — University of Illinois Museum of Natural History No. 42987, an adult male, collected by John Werler on the east slope of Volcan San Martin Pajapan at 4,000 feet elevation, Veracruz, Mexico, September, 1954. Field number 1317.

Diagnosis. — An *Eleutherodactylus* of the *E. rhodopis* group, separable from all species of the genus by the following combination of characters: tympanum nearly as large as eye, circular in outline, very distinct; tarsus with a weak but complete fold; head broader than body; no dorsal ridges except for a partial dorsolateral fold; toes with a vestige of a web; no supernumerary tubercles; large vomerine tooth bosses present; snout in lateral view sloping, not truncate or projecting over lip; side of head uniformly dark; dorsum much lighter, tan, with numerous paired markings; toe tips not dilated or bulbous; inguinal gland lacking.

Description of the holotype. — Adult male; head slightly broader than long (18.4 mm x 17.7 mm); snout very elongate; eyes small, width of eyelid smaller than interorbital distance; tympanum very large (Fig. 1), circular, its horizontal diameter nearly equal to length of eye; eye to nostril distance greater than length of eye; tip of snout (in lateral view) sloping; canthus rostralis sharp; loreal region slightly concave, sloping sharply to lip; supra- and posttympanic fold present, although supratympanic portion not prominent; a few glandular-like warts at angles of jaws.

Tongue oval, free for slightly less than one-half length of tongue, notched behind; vomerine tooth bosses triangular in outline, 5-7 vomerine teeth on bosses (right and left, respectively); choanae very large, approximately two and one-half to three times size of a vomerine tooth boss; vomerine tooth bosses between and a little posterior to choanae; choanae completely visible when roof of mouth is viewed from directly below; no vocal sac or vocal slits in mouth.

Head much broader than body; body relatively slender; skin of dorsum and venter smooth; dorsolateral folds present in form of rows of tubercles from supra- and posttympanic fold extending about



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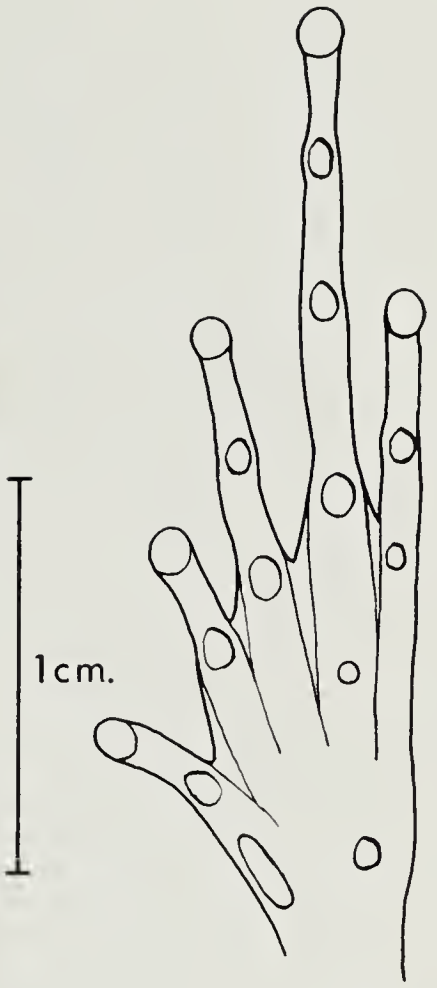

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Figure 1.—A, side of head of holotype of *E. werleri*. B, dorsal view of holotype. C, undersurface of foot of holotype. Holotype UIMNH 42987, Volcan San Martin Pajapan, 4000′, Veracruz, Mexico.

TABLE 1.—Comparison of species of *Eleutherodactylus rhodopis* group.

	lateral snout shape	head width	tarsal condition	Tympanum	tympanum size	supernumerary tubercles on sole	toe webbing	outer metatarsal tubercle	side of head
E. beatae	rounded	narrower than body	tubercle	oval	small	present	absent	clearly evident	not uniformly darkened
E. dorsoconcolor	rounded	narrower than body	tubercle	oval	small	present	absent	clearly evident	not uniformly darkened
E. dunni	rounded	narrower than body	tubercle	oval	small	present	absent	clearly evident	not uniformly darkened
E. rhodopis (*E. rostralis*)	rounded	narrower than body	tubercle	oval	small	present	absent or weak	clearly evident	not uniformly darkened
E. sanmartinensis	rounded	narrower than body	tubercle	oval	small	present	absent	clearly evident	not uniformly darkened
E. loki	truncate	narrower than body	tubercle	oval	small	present	absent	clearly evident	not uniformly darkened
E. venustus	rounded	narrower than body	tubercle	oval	small	present	absent	clearly evident	not uniformly darkened
E. macdougalli	sloping	broader than body	fold	oval	large	absent	present	clearly evident	not uniformly darkened
E. lineatus	sloping	broader than body	fold	oval	large	absent	present	clearly evident	not uniformly darkened
E. werleri	very sloping	much broader than body	fold	circular	large	absent	present	weakly evident	uniformly darkened

one-half the length of body; vague indications of postocular folds; no other dorsal skin folds present; no dark markings on center of back; skin in area of posterior and ventral surfaces of thighs and close to anus, granular; anal opening simple, no flap or large tubercles at opening.

No axillary membrane; no ridges on forearm; a single medial carpal tubercle present; a transverse fold at junction of forearm and hand; two large palmar tubercles, subequal in size; subarticular tubercles simple, not divided; vestige of web present between fingers; lateral fringes on fingers 2, 3 and 4; tips of fingers not expanded; transverse groove across tip of each finger; first finger slightly longer than second, shorter than fourth; third finger longest.

Tibiotarsal articulation reaches almost to nostril when leg carried forward; when legs held at right angles to body, heels overlap slightly (3 mm); no outer tarsal fold; inner tarsal fold weak, extending nearly the length of tarsus; inner metatarsal tubercle large, elongate, nearly four times as long as wide; outer metatarsal tubercle small, compressed, nearly indistinguishable from sole except by its darker color; no supernumerary tubercles on sole; subarticular tubercles simple; lateral fringes present on all toes; toes with slight but noticeable web; toe tips not expanded.

Measurements of holotype in millimeters. — snout to vent 43; length of tibia 23.5; width of head 18.4; length of head 17.7; horizontal diameter of tympanum 4.4; length of eye 4.8; distance from eye to nostril 5.7; width of eyelid 4.0; width of interorbital distance 4.8.

Color in alcohol. — Dorsum reddish brown, grayer on sides; side of head dark, almost uniformly black; narrow white-edged labial stripe extending from snout to commisure of jaws.

Specimens examined (all UIMNH). — *E. beatae*: Veracruz-Tequeyutepec 49186-94; Cuautlapam 15829-34. *E. dorsoconcolor*: Veracruz-Tequeyutepec 49195; Coyame 36858, 33912. *E. dunni;* Veracruz-San Martin 35364-68; Tequeyutepec 15843-97; Oaxaca-Cerro Machin 50081-100; Guatemala-Peten; 14710-32. *E. macdougalli*: Oaxaca-La Gloria 15907 (holotype); between La Gloria and Cerro Azul 40934-41; north of Zanatepec 53086. *E. loki*: Veracruz-Volcan San Martin 35383-86 (paratypes); *E. rhodopis*: Chiapas-La Esperanza 14656-680; Tonala 37433-37; Rancho San Vartolo 9881-86; Oaxaca-vicinity of La Gloria, Rio Grande, and Cerro Azul 40942-49, 40986-91; 3 miles W Tapanatepec 39497-518; Veracruz-San Lorenzo, nr. Cordoba 15933; Potrero Viejo 14584; San Andres Tuxtla 15927-29; San Martin 35370-82; Tequeyutepec 15935-36; Coyame 36863-64; near Jalapa 15934; Guatemala, Suchitepequez-E. Naranjo, W Slope Volcan Santa Clara 46216-44; Peten 14585-653. *E. sanmartinensis*: Veracruz-Volcan San Martin 33912, 35369, 35387 (paratypes). *E. venustus*: Veracruz-Cuautlapam 159-59; Tequeyutepec 15956-58, 49206-07; Chiapas-Tapachula 15960; Salto de Agua 15971; Oaxaca-km 110, Oaxaca to Tuxtepec road 53085; Guatemala, Suchitepequez-E Naranjo, W Slope Volcan Santa Clara 46357-61.

Comparisons. — Table 1 presents a comparative chart showing the differences in the several species of *Eleutherodactylus*. *E. werleri* is closest to *E. macdougalli* (Mexico) and *E. lineatus* (Guatemala) as evidenced by similarity in habitus, absence of supernumerary tubercles on sole, tympani size and color. We hesitate at this time to recognize *E. rostralis* as recognized by Duellman (1963:222) and Stuart (1963:30) in view of the variation which obtains in *E. rhodopis*. All named forms of the group are tentatively recognized until a comprehensive review of the group proves otherwise.

Etymology. — The new species is named for John Werler, the collector of the type. We wish to thank Dr. Hobart M. Smith for criticizing the manuscript.

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EARLY PRUNING OF LOBLOLLY PINE: EFFECTS ON WEEKLY GROWTH AT VARIOUS LOCATIONS ON THE STEM

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ABSTRACT. — Loblolly pine was pruned to 20, 40, and 60 percent and the weekly radial growth was determined at various locations on the stem.

Results the first year following pruning showed that trees varied considerably in their rates of stem growth; pruning delayed growth initiation and reduced growth rate with the most drastic pruning having the greatest effect; growth was greatest in the crown and decreased as distance below the live crown increased; height growth was not affected by intensity of pruning.

Lower branches of trees eventually die and are shed by natural processes, commonly resulting in large knots that degrade the wood and reduce pulp and veneer yields. This is especially true for trees growing at wide spacings where crown closure is very slow. Thus, artificial pruning is practiced to increase the ultimate value of the tree.

When live branches are removed, growth of the tree may be affected. Numerous researchers (Staebler, 1963) have reported that a substantial reduction (35 to 70 percent) of the living crown results in decreased height and stem growth. Only a few pruning studies have considered growth of the bole above breast height (Young and Kramer 1952, Heidmann 1963, Staebler 1963) and with the exception of Young and Kramer, these studies have dealt with growth only on a yearly basis.

The effect of artificially pruning loblolly pine (*Pinus taeda* L.) on weekly radial growth at various locations on the stem are reported in this paper. The study was conducted on a 10-year-old plantation at the Dixon Springs Agricultural Center in southern Illinois.

METHODS

Sixty-six trees used in the study averaged 4.1 inches in diameter at breast height (4.5 feet) and 23 feet in total height. The live crown on all trees extended down to at least breast height. Trees within 15 feet of each study tree were removed prior to the initiation of the experiment to reduce competition for soil moisture and sunlight. Limbs on the study trees below breast height were removed to eliminate any possible effect that they might have on the experiment. Dial-gauge dendrometer stations as described by Brown et al. (1947) were established at 4.5 feet, 8.5 feet and 12.5 feet above the ground if the bole was large enough to accommodate them; otherwise two or one dendrometer stations per tree were installed (hereafter referred to as either three station trees, two station trees or one station trees). Weekly radial measurements were taken at all dendrometer stations for one growing season before and after the trees were pruned.

Pruning treatments consisted of removing all limbs from the lowest

0 (control), 20, 40, and 60 percent of the stem, as measured between breast height and top of the tree. The origin of the limb on the stem determined if a limb was to be included in a pruning group.

Growth was computed as percent of control, percent decrease of actual to expected, and percent of previous year.

Results

Trees varied considerably in their rates of growth (Table 1). Growth before pruning varied from a low of 74 percent in the three station trees to a high of 124 percent in the two station trees. At the 8.5 foot station, growth varied from 75 to 115 percent. Variation in growth was also considerable at the 12.5 foot station. After pruning, growth varied to a lesser extent.

Decrease in the growth rate as a percent of the difference between expected growth and actual growth to expected growth is shown in Table 1. Reduction in growth occurred at all locations on the stem except in the 20 percent pruned trees at 4.5 feet for the one station trees. Although reduction in growth was not always statistically significant, it could be attributed to pruning. Treatment comparisons were highly significantly different with the following exceptions: 0-20 percent pruning treatments at all locations; 40-60 percent treatments of the two station trees; 0-40 and 20-40 percent treatments of the three station trees. There were significant differences in growth rate between the lower and upper station of the three station trees pruned to 60 percent and between the 8.5 and 12.5 foot locations of the three station trees pruned to 40 and 60 percent.

Accumulative growth after pruning is shown in Figures 1, 2 and 3 as a percentage of the previous year's total growth before pruning. There were no statistical differences in growth between the 0-20, 0-40, and 20-40 percent treatments of the three station trees. Neither were there differences between the 0-20 and 40-60 percent treatments of the one and two station trees. Growth was consistently greater on the control and 20 percent pruned trees than on the 40 and 60 percent pruned trees. Growth was reduced most by 60 percent pruning. Growth of the 40 percent pruned trees was less than the trees pruned 20 percent except at the 12.5 foot station in the three station trees.

Pruning affected growth early in the season with most drastic pruning having the greatest effects. Trees pruned 60 percent did not begin growing at any location on the stem to any appreciable extent until nearly 40 days after the controls and 20 percent pruned trees. Trees pruned 40 percent were also slow in starting growth but less so than trees pruned 60 percent.

On all trees, the rate of growth was slow in the spring increasing rapidly before reaching a maximum in early summer and then diminishing. Growth was erratic and no weekly growth pattern was detected in any group of trees. Growth was always greatest at the top station and in the crown, decreasing as distance below the live crown increased with more pronounced differences as more of the live crown was removed.

TABLE 1.—Cross-Sectional Area Growth Before and After Pruning and Decrease in Growth Rate Due to Pruning.

Percent crown pruned	No. Trees	Before		After		Expected growth in 0.010 Sq. ft.[1]	Difference between expected and actual	Percent decrease in growth rate
		0.010 Sq. ft.	As percent of control	0.010 Sq. ft.	As percent of control			
				ONE STATION TREES				
				4.5 Feet Location				
0	5	361	100	356	100	356	0	0
20	3	380	105	414	116	374	40	—11[2]
40	4	296	82	173	49	292	119	41
60	3	353	98	94	26	349	255	73
				TWO STATION TREES				
				4.5 Feet Location				
0	8	463	100	471	100	471	0	0
20	7	506	109	474	101	513	39	8
40	8	574	124	298	63	584	286	49
60	6	526	114	113	24	537	424	79
				8.5 Feet Location				
0	8	398	100	456	100	456	0	0
20	7	454	114	451	99	520	69	13
40	8	456	115	251	55	524	273	52
60	6	427	107	143	31	488	345	71
				THREE STATION TREES				
				4.5 Feet Location				
0	6	668	100	628	100	628	0	0
20	6	731	109	601	96	685	84	12
40	5	491	74	328	52	465	137	29
60	5	661	99	176	28	622	446	72
				8.5 Feet Location				
0	6	610	100	557	100	557	0	0
20	6	639	105	582	104	585	3	0
40	5	457	75	331	59	418	87	21
60	5	654	107	193	35	596	403	68
				12.5 Feet Location				
0	6	549	100	599	100	599	0	0
20	6	463	84	453	76	503	50	10
40	5	394	72	420	70	431	11	3
60	5	438	80	278	46	479	201	42

[1] Based upon pre-treatment; for example, 105 percent of 356 = 374.
[2] A negative (—) sign indicates an increase.

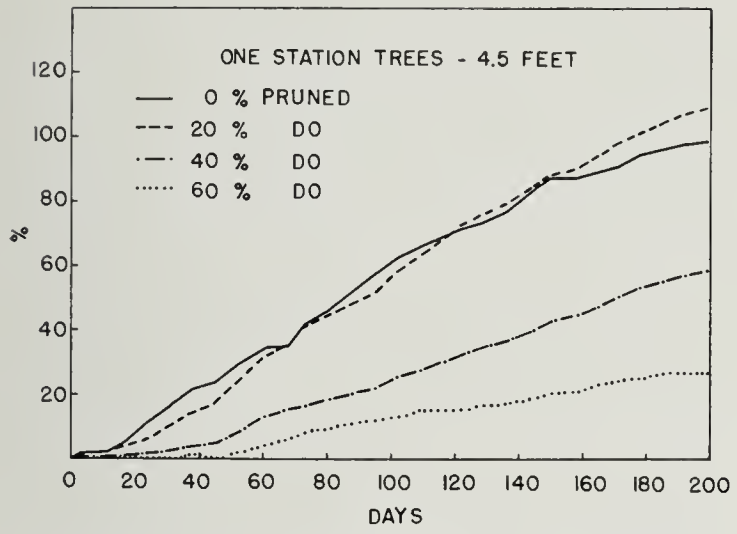

Figure 1. — Accumulative growth according to percent crown pruned and location on stem—one station trees.

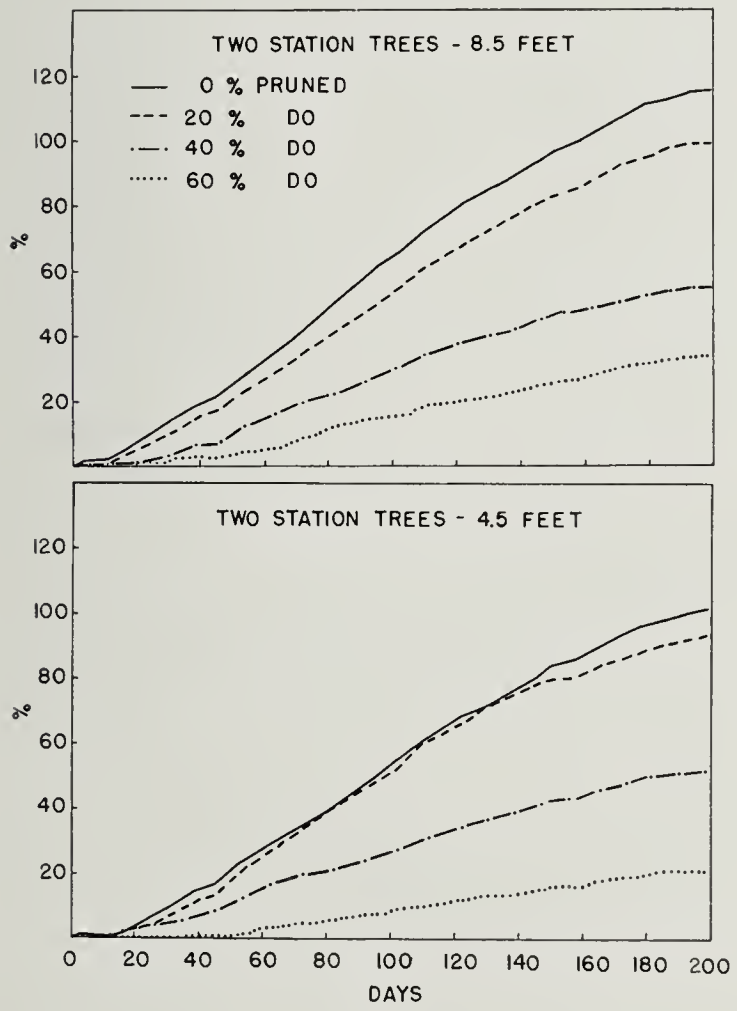

Figure 2.—Accumulative growth according to percent crown pruned and location on stem—two station trees.

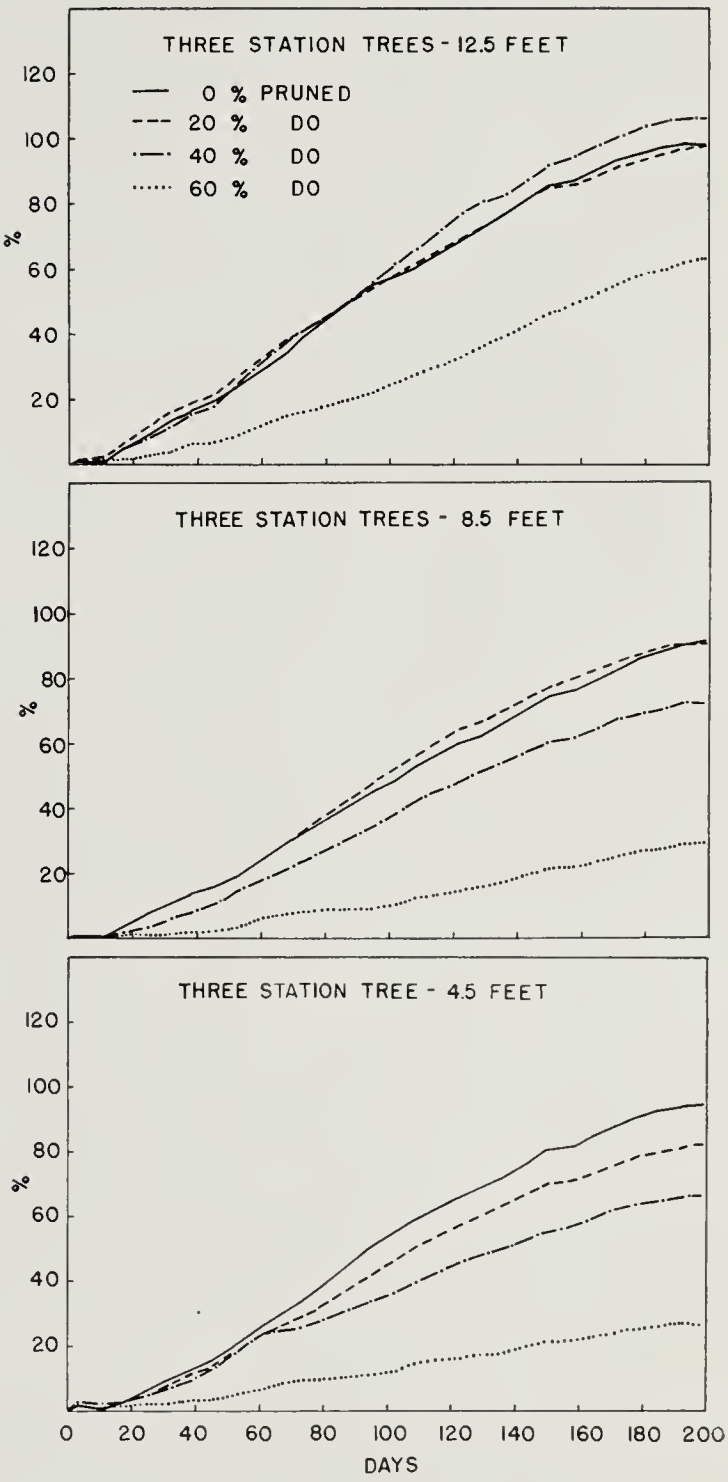

Figure 3. — Accumulative growth according to percent crown pruned and location on stem—three station trees.

Discussion

The method used to compute growth in this study assumes that an increase or decrease in growth according to the potential of the trees, as indicated by growth before treatment, is a satisfactory method of expressing growth. A tree may for some unknown reason(s) change its yearly growth pattern. But by using a number of trees per treatment, the effects of changeable yearly growth rate (if it exists in this study) should be eliminated or at least relegated to a minor status.

The method used in this paper to compute the percent of crown to remove is slightly different from most reported studies and should be re-

membered when trying to compare pruning as reported here with pruning reported elsewhere. Never-theless, these results demonstrate that removing about 40 percent of the live crown usually results in a reduction of stem diameter growth.

Stem growth is not affected by the removal of less than 40 percent of the live crown because water is used more efficiently. Unthrifty lower branches of a tree lose more carbohydrate through respiration than they add from photosynthesis (Takahara, 1954). When these branches are removed, more moisture is available to the remaining thrifty branches without a loss in photosynthate. Labyak and Schumacker (1954) demonstrated that the typical branch located at 15 percent of tree length below the free tip contributes maximum volume to the stem.

A probable reason why no significant growth difference occurred between the 40 and 60 percent pruned trees of the two station trees, is that some of the trees supposedly pruned 40 percent were actually pruned more. As stated in the methods, the origin of the limb on the stem determined whether a limb was to be pruned. Because of this rule it is possible to over-prune. As an example, a thirty foot tree to be pruned 40 percent will have all limbs below 14.7 feet removed. If there should be no limbs between 14.7 feet and the point that represents the 60 percent pruning (19.8 feet), then 60 percent and 40 percent pruning of the live crown are the same. This may explain why growth of one tree of the two station trees pruned 40 percent was very small in comparison with the other trees similarly treated. If this tree is disregarded in the analysis of variance, there is a significant difference between the 40 and 60 percent pruned trees at the 4.5 foot location but not at the 8.5 foot location.

A probable reason that stem growth was slow in starting in trees that had been pruned 60 percent (Fig. 3), is that there was not enough growth substance (auxin and/or vitamin) or carbohydrates produced by the remaining small crown. However, the different rate of growth at all three stations for the 60 percent pruned trees indicates that this limiting factor might be carbohydrates and not an auxin or a vitamin. Trees pruned 40 percent tend to bear this out in that they began growth later than the control trees, but not as late as the severely pruned trees. It is conceivable that growth had commenced at this early date but was proceeding too slowly to be detected by the method used in the study.

The tendency for trees to be erratic in their growth has been shown by a number of workers. But pine trees do not exhibit this erratic growth on an individual stem, as Young and Kramer (1952) observed that when growth at any location on the main stem either increased or decreased, all locations on the main stem grew in a like manner.

The fact that height growth was not affected by pruning does not conform with Slabaugh's (1957) report with red pine. He found that a light pruning (30 percent) had little effect, but more than this amount reduced height growth the first year. It was expected that height growth would be affected since four trees

died the first year from excessive pruning. If height of the trees had been measured for a number of years after being pruned, it is logical to expect that height growth would be found to be reduced.

The use of a dendrometer to measure growth of a tree has certain disadvantages as stem growth is not uniform (Bormann and Kozlowski, 1962) but it permits the results of cultural operations to be followed immediately and to detect trends. This study has been conducted for only one year but a trend has been established. Reported pruning studies (Stein 1955, Blockman and Roe 1958, Staebler 1964) indicate that this trend should continue for a number of years in the most drastic pruning treatment but not necessarily in the lighter pruning treatments.

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CARBOHYDRATE METABOLISM OF *DEBARYOMYCES GUILLIERMONDII*

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ABSTRACT. — Metabolism in strain Y-1448 of *Debaryomyces guilliermondii* was studied by incorporating glucose-1-C^{14} in the medium. C_1 of glucose underwent oxidation to CO_2 at a more rapid rate at the initial period of metabolism than in the later phase. The results suggest that an initial rapid utilization by the pentose phosphate pathway which decreases in rate with the time while another one, presumably the Embden-Meyerhof pathway, continues to operate; that lactose was utilized by the organism; and that the organism can oxidize galactose.

Debaryomyces guilliermondii is a membrane-forming yeast, the taxonomy of which has been studied only in recent years (Lodder and Kreger van Rij, 1952). A few reports are available on certain aspects of the physiology and on the functional requirements of the organism (Stelling-Dekker, 1931; Wickerham and Burton, 1948; Wickerham and Burton, 1954; Etchells and Bell, 1950; and Merdinger and Shair, 1962). According to Giovannozzi, 1941, and Mrak and Bonar, 1939, *D. guilliermondii* is not able to utilize lactose, starch, or dextrin, but the same authors are in disagreement as to its ability to utilize galactose.

Because of the limited knowledge in this area, the present study of the intermediary metabolism of *D. guilliermondii* was undertaken. As previous studies from this laboratory had shown that the strain N R R L Y-1448 of *D. guilliermondii* utilized lactose with the evolution of CO_2, the intent of the present investigation was to determine the amount of CO_2 released when lactose was used as a source of carbon and the amount of $C^{14}O_2$ given off when glucose-1-C^{14} was used as a substrate over intervals of 3 and 5 days.

MATERIALS AND METHODS

Malt extract, yeast extract, lactose, glucose, galactose, soluble starch and dextrin were Difco preparations. Glucose-1-C^{14} was obtained from the Nuclear Instrument Corporation and Volk Radiochemical Co.

The basal culture medium contained 0.3% malt extract, 0.3% yeast extract, 2% NaCl, nutrient salt mixture recommended by Wickerham, 1946, and either 5% glucose, 5% lactose, 5% galactose, 1.5% soluble starch, 2% dextrin or lactose broth with additional 4.5% lactose without Wickerham's nutrient salt mixture. A loopful of a 48 hr culture of *D. guilliermondii* strain NRRL Y-1448 was introduced into a 50 ml Erlenmeyer flask containing 20 ml of sterile glucose medium. The phosphate salts were sterilized separately and added to the sterilized medium. After 48 hr of incubation at 30°C the medium was transferred into a 500 ml flask containing 230 ml of sterile glucose medium. A total of 2 ml of

solution containing approximately 4.75 μ of glucose-1-C^{14} was then added and the contents shaken on a reciprocating shaker or by a magnetic stirrer. The flask was then attached to a series of 3 interconnected flasks on one side and 4 on the other. The first two flasks each contained 150 ml of 10% NaOH, the third, 300 ml of saturated $Ba(OH)_2$, the fourth, substrate and the organism; the fifth, 1000 ml of saturated $Ba(OH)_2$, and the remaining three, 500 ml each of the last solution. The temperature of the medium was 31°C. Air was drawn through the train of the 8 flasks at a slow constant rate.

Several 1 ml samples of the substrate containing the glucose-1-C^{14} were pipetted and emptied into either stainless steel planchets or suitable glass vials before and at the end of 3 and 5 day experimental periods for measurement of radioactivity. $BaCO_3$ was recovered from the last four flasks of the train and washed with water and ethanol and then dried at 200°C for 2 hr. Radioactivity was ascertained in the planchets with a Gas Proportional Counter. A Packard Tri-Carb liquid scintillation spectrometer was employed with the samples in the glass vials.

Similar procedures were applied to the substrate containing the basal medium and 5% lactose and for the broth to which 4.5% lactose was added but without Wickerham's salt mixture. Galactose utilization was tested with cells which had been transferred three times in a medium containing only galactose. Each experiment was accompanied by controls which were identical except for the absence of the organism. In the experiments with labeled glucose, the corresponding controls were devoid of any tagged glucose.

Results and Discussion

The $BaCO_3$ obtained from the experiment with glucose-1-C^{14} amounted to 1.91 gm after 3 days and 3.1 gm after 5 days as shown in Table 1, whereas the controls yielded 1.87 gm and 3.06 gm of $BaCO_3$ for the respective intervals. The rate at which $C^{14}O_2$ was produced in 3 days was more rapid than the one in the 5 day run. The decrease in the rate of $C^{14}O_2$ production is also reflected by the values given as total percent of $C^{14}O_2$ collected.

An increasing amount of evidence is being presented relative to the fact that certain organisms catabolize glucose at first much faster through the hexosemonophosphate shunt by converting glucose-C_1 into CO_2 rath-

Table 1.—Utilization of Glucose-1-C^{14} by *Debaryomyces guilliermondii*. In each experiment 4.75 μ of Glucose-1-C^{14} was added to the incubation flask.

Days of incubation	Grams of $BaCO_3$ collected	Specific activity of $BaCO_3$ counts/g	Total activity recovered in microcuries	Average glucose–1–C^{14} per day in microcuries	Percent of glucose–1–C^{14} recovered
3	1.91	0.231	0.438	0.146	9.2
5	3.10	0.165	0.512	0.102	10.8

er than through other pathways. In the later phases, however, the Embden-Meyerhof scheme prevails (Koshland and Westheimer, 1950; Blumenthal et al., 1954; Horecker et al., 1954; Claridge and Werkman, 1954; and Clark and Wallace, 1958). The present findings obtained with glucose-1-C^{14} indicate that the hexosemonophosphate scheme is a pathway of glucose breakdown in *D. guilliermondii*. That the Embden-Meyerhof scheme also occurs is supported by the findings of Merdinger and Shair, 1962, who isolated pyruvate as well as ethanol and acetate.

The amount of $BaCO_3$ obtained from 5% lactose with the nutrient salt mixture and lactose broth without the nutrient salts over a period of 5 days was 3.2 gm and 2.1 gm, respectively. The higher rate of metabolic activity in the former medium was probably due to the presence of the nutrient salts. Since the organism produced nearly the same amount of CO_2 with lactose as with glucose duirng the same interval of time, it can be inferred that *D. guilliermondii* can utilize both carbohydrates equally well and that it possesses the enzyme system for the hydrolysis of lactose.

In corroboration of the finding of Giovannozzi, 1941, qualitative tests, carried out with 5% galactose in the basal medium, point to the ability of the organism to metabolize this carbohydrate. In those experiments employing starch or dextrin as the source of carbohydrate, the organism failed to grow, which confirms previous reports.

Summary

Experiments in which glucose-1-C^{14} was administered to a strain of *Debaryomyces guilliermondii* showed that it oxidizes C_1 as C_1O_2 at first much faster than other carbon atoms of glucose. The organism appears to utilize lactose at the same rate as it does glucose since the amounts of $BaCO_3$ obtained with either sugar, collected after 5 days, are practically the same. The organism grows well with galactose as a single source of carbon.

Acknowledgments

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RAT DIAPHRAGM METABOLISM IN THE PRESENCE OF THYROACTIVE HORMONES, PRECURSORS AND GOITROGENS

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ABSTRACT. — Mean changes in oxygen and glucose uptake and glycogen content of the isolated rat diaphragm incubated in phosphate-saline medium containing 120 mg % of glucose have been evaluated in the presence of 3-iodotyrosine (1.00 mg), 3,5-diiodotyrosine (1.00 mg), D-thyroxine Na • $5H_2O$ (0.25 mg), L-thyroxine Na • $5H_2O$ (0.25 and 2.50 mg), 3,5,3′-triiodothyronine Na (0.25 mg), bovine thyroglobulin (1.00 mg), thiourea (1.00 mg), 6-propyl-2-thiouracil (0.25 mg) and DL-thyronine (0.10 and 1.00 mg) and were found to be significant only for the last agent and at the higher level. In this case, the Qo_2 and glycogen content were markedly depressed. Possibly, a borderline significance can be attached to the decrease in mean glucose content observed with TSH (1.67 IU).

Reisser (1947) interpreted equivocal data as perhaps pointing to an increase in rat diaphragm glycogen synthesis with thyroxine (0.1-0.5 mg) or rat thyroid extract in a medium containing 500 mg % of glucose. This paper presents a pharmacological study undertaken on the isolated rat diaphragm to elucidate a possible role of thyroxine and triiodothyronine and precursors in muscle glucose utilization and glycogen turnover.

MATERIALS AND METHODS

Except for the bovine thyroglobulin and TSH obtained from Sigma Chemical Company, the source of the test agents was Nutritional Biochemicals Corporation. The TSH contained 1 U.S.P. unit (or 1 IU) per mg and was reported to be almost free of STH, gonadotrophins, ACTH and posterior pituitary activities. The phosphate-saline medium of Stadie and Zapp (1947) was employed in the incubation of diaphragms, the glucose content being 120 mg %. It was prepared double strength. The test agents were dissolved in physiological saline and the pH brought to 7.0 with sodium hydroxide in the case of the iodo-tyrosines and DL-thyronine. Saline or a solution of saline containing the specified weight of test agent in 1.0 ml was added to an equal volume of double strength Stadie phosphate-glucose medium per Warburg vessel. These comprised the control and treatment flasks, respectively.

Male rats purchased from the Holtzman Rat Company, Madison, Wisconsin, and weighing 130-165 gm at the time of experimentation, were starved for 24 hr in order to deplete diaphragm glycogen. They were sacrificed by swift decapitation, incised and the hemidiaphragms rapidly removed. Care was taken to avoid trauma and cutting of the vena cava. The hemidiaphragms were chilled in saline, trimmed, blotted between filter paper, weighed and introduced into

the Warburg flasks. One hemidiaphragm was incubated with the phosphate-saline control and the other muscle portion, with the treatment mixture or medium plus test agent. Controls which contained the media without tissue were also included. The flasks were connected to the manometers, the system gassed with oxygen for 10 min. and incubated in the bath at 37.5° C for 1 hr. The hemidiaphragms were then removed, rinsed with saline, blotted and immediately digested with 30% KOH. The glycogen which was precipitated in the presence of sodium sulfate on addition of ethanol according to the Walaas and Walaas (1950) modification of the Good, Kramer and Somogyi procedure (1933) was determined by Dreywood's anthrone reagent (Morris, 1948). Glucose in the incubated mixtures was analyzed following dilution 1:5 with water and deproteinization (Nelson, 1944; Somogyi, 1945). Six rats were employed per Warburg run and involving two test agents.

Results and Discussion

Mean changes in rat diaphragm Qo_2 glucose uptake and glycogen content in the presence of mono-and diiodotyrosines (each at a level of 1.00 mg), D-thyroxine (0.25 mg), L-thyroxine (0.25 and 2.50 mg), 3,5,3′-triiodothyronine (0.25 mg), DL-thyronine (0.10 and 1.00 mg), bovine thyroglobulin (1.00 mg), TSH (1.67 IU), thiourea (1.00 mg) and propylthiouracil (0.25 mg) together with the pertinent Fisher t values appear in Table 1. The levels of thyroxine and triiodothyronine are in terms of the sodium salts as specified. The contents of the flask containing 2.5 mg of the thyroxine salt occurred as a fine cloudy suspension. A statistical method which may be applied only to bulk data and where an experimental design is not followed, was employed to eliminate any possible questionable data. Individual differences were excluded which exceeded $R \pm 2.5\ R$, R being the average range (Grant, 1952).

At the given concentrations, none of the test agents elicited any statistically significant effect on the mean oxygen and glucose uptakes or the glycogen content of the isolated rat diaphragm except for DL-thyronine in amount of 1.00 mg or 3.7 μM. With the latter, Qo_2 and glycogen were both definitely depressed, but the mean decrease in glucose uptake was not marked; the corresponding results were equivocal with 0.10 mg of the thyronine as well as with the L-thyroxine salt at the comparably high level.

Attention is called to the case of TSH (1.67 IU) which caused a depression in mean glucose content of low or only borderline significance (t, 2.09; $P = 0.05$), findings which might be in contrast to those observed with isolated thyroid. Thus, Field and coworkers (1960) reported that TSH produced an increase in glucose uptake by thyroid slices.

Acknowledgement

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TABLE 1.—Mean Changes in Oxygen Uptake and Glucose and Glycogen Contents of Rat Diaphragms Incubated with Iodoamino Acids, Thyronine, TSH and Goitrogens[a,b].

Agent (mg)	Mean Q_{O_2} Change		Mean Glucose Difference[c]		Mean Glycogen Difference	
	μl/mg wet tissue/hr	t	μg/mg wet tissue/hr.	t	μg/mg wet tissue/hr	t
3-Iodo-L-tyrosine (1.00)	—0.04 ± 0.084 (19)	0.46	0.19 ± 0.643 (17)	0.29	0.01 ± 0.057 (17)	0.21
3, 5-Diiodo-L-tyrosine (1.00)	0.01 ± 0.048 (10)	0.18	0.62 ± 0.485 (8)	1.27	0.06 ± 0.047 (11)	0.86
DL-Thyronine (0.10)	0.06 ± 0.048 (14)	1.26	0.50 ± 0.391 (13)	1.27	0.06 ± 0.037 (13)	1.60
DL-Thyronine (1.00)	0.17 ± 0.045 (17)	3.76**	0.25 ± 0.333 (15)	0.76	0.25 ± 0.062 (16)	4.08**
D-Thyroxine (Na)·$5H_2O$ (0.25)	0.12 ± 0.063 (12)	1.83	0.28 ± 0.354 (11)	0.80	0.02 ± 0.067 (12)	0.32
L-Thyroxine (Na)·$5H_2O$ (0.25)	—0.01 ± 0.047 (22)	0.07	0.13 ± 0.431 (10)	0.31	—0.04 ± 0.035 (23)	1.06
L-Thyroxine (Na)·$5H_20$ (2.50)	—0.03 ± 0.048 (12)	0.67	—0.88 ± 0.793 (10)	1.11	—0.11 ± 0.094 (13)	1.21
L-3, 5, 3'-Triiodothyronine (Na) (0.25)	0.01 ± 0.065 (10)	0.18	0.62 ± 0.475 (9)	1.31	—0.01 ± 0.032 (11)	0.30
Bovine thyroglobulin (1.00)	0.03 ± 0.051 (9)	0.60	—0.48 ± 0.301 (11)	1.59	0.05 ± 0.090 (10)	0.58
TSH (1.67 IU)	—0.01 ± 0.032 (19)	0.44	0.72 ± 0.344 (21)	2.09*	—0.01 ± 0.047 (21)	0.30
Thiourea (1.00)	—0.07 ± 0.049 (16)	1.36	1.34 ± 0.772 (11)	1.74	—0.07 ± 0.076 (15)	0.86
6-Propyl-2-thiouracil (0.25)	0.04 ± 0.068 (13)	0.62	—0.04 ± 0.372 (11)	0.11	0.09 ± 0.050 (15)	1.80

a. The means (± S.E.) are deduced from the specific number of paired hemidiaphragms given in the parentheses.
b. A positive mean difference indicates a decrease in response in the presence of the test agent.
c. The extent of glucose utilization was based on the final concentration of the respective media incubated without diaphragm.
** $P < 0.01$.
* $P = 0.05$.

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THE EFFECT OF THYROID HORMONES ON THE GROWTH OF GOLDFISH, *CARASSIUS AURATUS* (L.)

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ABSTRACT. — Synthetic thyroid hormones increase the efficiency of food conversion in the goldfish, *Carassius auratus* (L.). However, preparations of parrot fish thyroid gland capable of producing increased oxygen consumption in laboratory mice fail to increase efficiency of food conversion in goldfish.

During experiments designed to study the morphogenic effects of thyroid hormones on the normal epidermis, the regeneration of scales, and the healing of superficial wounds of goldfish, it was found that prolonged administration of synthetic thyroid hormones temporarily increased the efficiency of food conversion in the goldfish, *Carassius auratus*, a natural hypothyroid. This effect was investigated.

MATERIALS AND METHODS

Linebred F_5 xanthic goldfish, *C. auratus* (L.), obtained from Ozark Fisheries, Inc., Stoutland, Missouri, were used in two experiments in which thyroid hormones were administered to goldfish thoroughly conditioned to laboratory life prior to treatment. Although all fish were less than one year old, it was possible to distinguish the males from the females by the presence of breeding tubercles on the first pectoral fin ray of the males. Fish were assigned to treatment in random fashion.

Experiments were conducted in 57 liter glass aquaria equipped with an airstone and airlift filter provided with glass wool and activated charcoal. The pH of the conditioned aquarium water was maintained at approximately 7.5 and oxygen content of the water was always above 6.0 ppm. Temperature was maintained at 21± 1.0 C. Daylight fluorescent lamps illuminated the aquaria 10 hours daily.

Hormones were administered by intra-abdominal injection on days 2, 5, 7, and 10 of each 10-day period. Fresh solutions, made each week in 0.65% saline, were buffered (Sorensen's phosphate) at pH 7.5 and stored in the freezing compartment of a refrigerator. Solutions were made so that, regardless of treatment, the total volume of injected fluid was the same for all animals of the same weight. Injection volumes were adjusted at 10-day intervals according to weight changes of individual fish. Fish were weighed to the nearest 0.05 gm on a triple beam balance accurate to ± 0.01 gm after excess water was lightly blotted with paper toweling. Standard and total lengths were recorded to the nearest 0.5 millimeter. Fish were anesthetized in MS 222 (Sandoz Chemical Co., New York, N. Y.) prior to handling. Individual

fish were identified by small electrocautery marks made on the operculum.

Regeneration of a "key scale", the seventh from the first row above the lateral line on the left side of the body was followed, and at necropsy, the orginal scale, its regenerate, and its opposite number from the right side of the body were compared.

Fish were fed an average of 1.7% of their body weight per day of a commercially prepared pelleted diet (Perk Foods Co., Chicago, Illinois) to which a bit of raw minced beef liver (less than 5% dry weight of the ration) was added on alternate feeding days. Actual food intake per feeding day was approximately 3% of the body weight per tank of fish, as fish were not fed on days when injections or measurements were scheduled. Food was added to aquaria throughout a feeding day to insure a minimum of waste. There was no mortality during this investigation. Specific growth was calculated from the formula

$$\frac{\log_e W_1 - \log_e W_0}{t_1 - t_0} \times 100$$

where W = weight and t = time.

Coefficients of growth were calculated from the formula

$$\frac{\text{food consumed}}{\text{gain in wet weight}} \times 100$$

Data were tested for statistical significance using the Kruskall-Wallis one-way analysis of variance by ranks (Siegel, 1956, p. 184). The level of significance chosen was alpha (α) = 0.05.

Results

An unexpected advantage in increments in weight and in standard length in fish treated with synthetic thyroid hormones occurred during the first 20 days of the two independently conducted experiments. Mean initial weights, mean percentage increases in weight, mean specific growth per day in weight, coefficients of growth, and mean absolute and percentage increases in standard length for the first twenty days of the two experiments are summarized in Table 1. Experiment two (females), January, was not begun until experiment one (males), October through December, was completed.

The males were maintained 70 days and showed no significant differences in the coefficient of growth between treated and untreated fish during the last 40 days of treatment ($p > 0.50$). The statistical tests were based upon the first three and the last four 10-day periods of the test because there is no good way of comparing two values from each of four treatments. The data for days 1 to 10 and 11 to 20 appeared significant. However, the hormonal effects were insignificant after the first 20 days, probably because of the well known pituitary-thyroid feedback mechanism, and adding a third 10-day interval in order to make a statistical test allows only a marginal rejection of the null hypothesis ($p < 0.10$ but > 0.05). In all intervals, fish treated with desiccated parrot fish thyroid grew at rates comparable to saline controls.

New circuli added at the margins of normal scales of males treated

TABLE 1.—Growth Responses of Goldfish to Treatment with Thyroid Hormones for the 20 days Following Initiation of Treatment.

Item	Treatment						
	Synthetic Hormones				Parrot Fish Thyroid	Saline	
	Thyroxin	Triiodothyronine					
	2 μg/gm body weight	2 μg/gm body weight		10 μg/gm body weight	5 μg/gm body weight		
Sex	male	male	female	female	male	male	female
Number of Fish	7	7	5	5	7	7	5
Mean Initial Weight (gms)	7.40	7.45	10.45	10.85	7.35	7.20	10.35
Mean Percentage Increase in Weight	15.8	15.4	15.6	16.0	11.5	10.5	11.6
Mean Specific Growth per day	0.65	0.61	0.62	0.60	0.47	0.44	0.48
Coefficient of Growth	44.4	43.9	44.0	44.9	32.7	30.2	33.0
Mean increment in Standard Length (cm)	0.21	0.25	0.32	0.33	0.14	0.16	0.22
Mean Percentage Increase in Standard Length	3.7	4.3	5.0	5.0	2.5	2.8	3.5

with thyroxin or triiodothyronine were more numerous after 70 days than in the saline control or parrot fish thyroid treated animals, seven males treated with thyroxin averaging 3.3 circuli, and seven males treated with triiodothyronine averaging 3.1 new circuli. In contrast, seven saline controls averaged 2.6 new circuli and seven fish treated with parrot fish thyroid extract averaged only 1.9 new circuli.

Discussion

Ideally the coefficient of growth should be based upon individual fish maintained in individual aquaria. The growth results were so unexpected that no provision for such analysis had been made in the design of experiments. Nothing in the literature at the time the experiments were conducted suggested the apparent increase in the efficiency of conversion of food observed here. The decision not to feed *ad libitum* was made to prevent overfeeding and consequent disease problems. Unfortunately the recent experiments of Gross, Fromm, and Roelofs (1963), the only published report of a similar effect of the thyroid on efficiency of food conversion in fish, were not idealized either.

The efficacy of the parrot fish thyroid powder used in these experiments was tested by Kenner, Bjorklund, and Gasdorf (1964), and found to significantly increase oxygen consumption in white laboratory mice. With this established, maturing goldfish were maintained two months in aquarium water containing desiccated parrot fish thyroid 1:38,000.

No growth or morphogenic responses were obtained even after goldfish were seen to swallow additional bits of parrot fish thyroid gland mixed with moistened pellets of the commercial food preparation. Therefore, neither processing of the glands nor dosage level appear to have caused the failure of the fish thyroid extract to elicit significant growth or morphogenic responses.

Despite the indications that thyroid hormones may be involved in promoting growth of fishes, decisive experiments using individual aquaria and including hypophysectomized fish treated with thyroid and growth hormones singly and in combination are very much in order. Chemical analysis of desiccated parrot fish thyroid gland collected at various times of the year using desiccated mamalian glands and synthetic thyroxin as reference standards would also be helpful.

Acknowledgments

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Parrot fish, *Pseudoscarus guacamaia*, thyroids were supplied by Drs. W. B. Suttcliffe, Jr. and D. W. Menzel of the Bermuda Biological Station.

Sodium L-thyroxin and Sodium L-triiodothyronine were obtained through the courtesy of Smith, Kline, and French Laboratories, Philadelphia, Pennsylvania.

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NEWS AND COMMENTS

Now it is October. In March you will read this section and, I hope, make plans to attend the Fifty-Eighth Annual Meeting—in DeKalb. Bring your promising undergraduate and high school students (both of whom can join the Academy for two dollars), new faculty members, new high school teachers, new graduate students, and anyone else you can dragoon into the ranks. The treasurer will be ensconced in some central location to sign on new members.

Bless the botanists. They sent more News. Two new faculty members, Professor William D. Gray and Professor Jacob Verduin, have been added to the Southern Illinois University Department of Botany.

Professor Gray, a native of Jeffersonville, Ind., received his Ph.D. degree in 1938 from the University of Pennsylvania. He was a Fulbright lecturer at the University College of Rhodesia and Nyasaland, and has been at Ohio State since 1947. Gray, whose specialties include general and industrial mycology and fungus physiology, currently is engaged in research dealing with the possible enlargement of the world's protein pool through the use of fungi. He has published extensively in a variety of scientific journals, and is the author of "The Relation of Fungi to Human Affairs."

Professor Verduin, formerly chairman of the biology department at Bowling Green (Ohio) State University, is a specialist in aquatic plant ecology, limnology and radio-biology. His research has been supported by both the National Science Foundation and the Atomic Energy Commission. He received his Ph.D. degree from Iowa State College in 1947 and taught at the University of South Dakota and Ohio State University before going to Bowling Green.

Paul B. Sears, emeritus professor at Yale University, joined the botany faculty for the winter term of this year. Dr. Sears, the author of *Charles Darwin the Naturalist, Deserts on the March, The Ecology of Man, This Is Our World*, and *Who Are These Americans*, to mention a few of his books, is a specialist in the fields of conservation and ecology. He served as Chairman of the Yale Conservation Program from 1950 to 1960. Dr. Sears is lecturing and serving as a Consultant on Conservation in planning the further growth of this important field at Southern Illinois University.

Professor Harvey I. Fisher, Chairman of the Zoology Department at Southern Illinois University and former Editor of the Transactions, is spending this school year on Midway Island continuing the long range study of Gooney Birds. Mrs. Fisher and a graduate student, Earl Meseth, are assisting him in the project.

NOTES

WILDLIFE KNOWLEDGE OF SOUTHERN ILLINOIS HIGH SCHOOL STUDENTS

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ABSTRACT. — A test on wildlife knowledge was given to 593 students in 20 high schools in southern Illinois. An analysis of the performance on various sections of the test was made and comments contributed as a basis for interpretation of the results.

Because of the increasing importance of conservation, it is of value to know the level of understanding of the subject by high school students so that educational programs can be better organized and evaluated. The activities of federal, state, local and private conservation agencies are ultimately dependent upon the acceptance of a wise resource-use policy by the public. High school students influence the opinions and attitudes of parents who may voice approval or disapproval of resource management techniques. On the other hand, students of high school age probably reflect the opinions held by parents; investigation of the student then will give indication of the conservation knowledge and attitudes of parents.

A survey in 1953 of conservation education in southern Illinois high schools (Klimstra and Oberheu, 1955) indicated that over 99 percent of 113 principals felt that high school graduates should have a basic knowledge of conservation. Eighty-four percent of these administrators were of the opinion that graduates of their schools possessed an inadequate concept of this subject. Further, most administrators thought that resource management was a necessary part of high school curricula.

As a follow-up to this initial study by the Cooperative Wildlife Research Laboratory, a project was organized in late summer of 1958 to evaluate the conservation knowledge possessed by high school students in southern Illinois; because of limited funds only wildlife conservation was emphasized. However, it was believed that this phase would yield information applicable to an evaluation of the level of understanding for other facets of resource use and management.

A test was prepared concerning organization and regulations of the United States Fish and Wildlife Service and the Illinois Department of Conservation, interpretation of the Illinois Fish and Game Code, and ecology, natural history, and management of wildlife. Following the preparation of an outline of material basic in wildlife management, multiple-choice items were prepared which dealt with a sample of all material which was outlined. Many items were designed according to those utilized by other investigators (Capps 1939, Curtis 1942, Giles 1958, Selim 1951, and Weivel 1947). Several items were included as modified from a test used by Dr. B. K. Barton, former Director of Conservation Education in Illinois; some were adapted from studies conducted by the Cooperative Wildlife Research Laboratory in sampling conservation knowledge of adults, and in the mail questionnaire of Klimstra and Oberheu (1955). The test, designed to be completed in one 40-minute class period, contained 48 fact questions and 21 questions requiring an opinion. Only factual questions were used in computing percentile scores.

As the test was being designed, evalution was obtained from wildlife graduate students at Southern Illinois University; wildlife personnel of several states; Dr. B. K. Barton, former Director of Conservation Education in Illinois; and, Dr. K. D. Orton, Guidance Department, Southern Illinois University. Prior to the final preparation, the test was pretested at University High School, Carbondale; the mean scores of all students, the range and normal curve of score distribution, and test reliability were found to be satisfactory.

The early plan of this project was to investigate one or two high schools in each of the 31 counties of southern Illinois. Accordingly, letters were sent to county school superintendents in August of 1958 outlining the study and asking for approval to administer the test; 13 superintendents responded. During October of 1958 principals of 22 high schools were contacted and tests and instructions provided. High schools of various sizes, including those in small and large towns, were selected. The test was administered to one section of Junior-level English. Twenty high schools returned the completed tests for 593 students.

Results

Data concerning testing period and the reaction of students to the test were supplied by each instructor administering the test. As indicated by the instructors, an average of 44.3 minutes was allowed for the students to complete the test. The test had been designed to be completed by the majority of students in 40 minutes; however, most students completed the examination in an average time of 34.5 minutes.

According to replies of individual instructors, the most frequent questions asked by students concerned the purpose of the test. Several students asked why they should take the test and why they had not been given instruction in the subject of conservation; others questioned whether or not the results of the test might influence school curricula. There was interest expressed in results of their performance and how they compared with other high schools. Frequent questions were raised about the correct answers on the test; two groups of students asked about sources of information for subject matter of the test.

The distribution of test scores indicated little skewness or kurtosis. Mean percentage score achieved was 38.1 with a standard deviation of scores of 9.1. The standard deviation compares favorably with that recorded by Capps (1939) (10.8), Curtis (1942) (10.3), Giles (1958) (19.3), and Selim (1951) (9.6).

The mean score for students of southern Illinois high schools was lower than that obtained by others who have given similar tests. Capps (1939) obtained a score of 47.6 percent while Curtis (1942) reported a score of 49.5 percent. Giles (1958), testing grades 6 through 12, reported an average score of 48.6 percent; however, students of Junior level in high school, averaged 62.2 percent. Selim (1951) reported an average of 56.6 percent and Wievel (1947), testing 9th and 12th grades, obtained an average score of 51.0 percent.

Of the 593 students, 333 females showed a score of 35.5 percent compared to 38.8 percent for 260 males. Inasmuch as the test stressed wildlife, the higher male score might be expected.

Analysis of the test results on the basis of subject matter showed that the highest mean score was attained in interpretation of items from the Illinois Fish and Game Code (42.6%); state and federal regulations and organizations ranked second with 39.0 percent; natural history third with 36.6 percent; management practices fourth with 34.3 percent; and ecology fifth with 30.5 percent. Students with the most successful score knew most about natural history whereas those with lowest scores seemed to be best informed about regulations and organization. However, neither the upper nor lower group averaged more than 50 percent on any category of questions.

The following represent some selected answers to questions which are believed to reflect the basis for much misunderstanding regarding administration of wildlife conservation in Illinois. Approximately 50 percent knew that a hunting license was required of everyone who hunts regardless of age, whereas, 27 percent indicated that the 17th birthday was the minimum age. When asked to interpret a section from the Fish and Game Code concerning the possession of game, only 17 percent gave the correct answer. The identification of the Director of the Illinois Department of Conservation was correctly given by only 34 percent. Fourteen percent knew that the United States Fish and Wildlife Service was a Bureau of the United States Department of Interior while 66 percent said it was a bureau of the Department of Fur, Fish and Game. About 50 percent knew that Illinois was in the Mississippi Valley Waterfowl Flyway. Regarding the basic principle for managing game animals 67 percent selected the incorrect answer, "solely to protect wildlife from extinction." In a question concerning the most effective long range wildlife management practice, 29 percent said supplying food and cover, 30 percent said placing restrictions on the hunter, and 31 percent said establishing refuges where no hunting is allowed.

Answers to the opinion type questions yielded information which should be of interest to parents, teachers, school ad-

ministrators and the State Superintendent of Instruction. Because of the nature of these questions, and their answers, some will be commented on.

When asked what mass media contributed most to their knowledge about wildlife, 54 percent said magazines, 21 percent television, 20 percent movies, 3 percent newspapers and 1 percent radio. Regarding their relationship with associates 28 percent said personal experience provided them with the greatest amount of knowledge, 25 percent family, 23 percent friends, 12 percent teachers, and 11 percent membership in clubs.

Seventy-six percent felt that their school did not place sufficient emphasis on conservation. In contrast the study by Klimstra and Oberheu (1955) revealed that 58 percent of the school principals felt that their schools did give adequate stress. These same school principals, however, indicated that 84 percent of their graduates did not have an adequate concept of conservation. Fifty percent of the students believed that most graduates have a fair amount of knowledge.

Among the students, 48 percent thought that if conservation was included in their curriculum, it should be integrated in specific courses. The survey of the principals by Klimstra and Oberheu (1955) showed that integration in specific courses was preferred by 64 percent.

Conclusions

The results of this survey suggest a number of factors which bear special enumeration:

1. The fact that 52 percent of those who took the test thought that it was easy indicated many were confident that they knew the answers; much of this probably reflected the influence of parents and friends. In fact, results of this test possibly reflected training at home as well as in school. This was believed especially evident in attitudes regarding stocking, predators, and hunting pressure.

2. Because only 12 percent indicated they learned most about conservation from their teachers implied that not much is emphasized, or that not much is learned, in the classroom. This may well be related to the background of teachers and the attitude of the administrators that natural science and agriculture instructors should be solely responsible for conservation training. A teacher certification requirement in conservation could contribute to a correction of this problem.

3. The mass media need attention and our support in dissemination of conservation information. Certainly magazines, television and movies could be vastly improved in quality and in distribution. These apparently already serve major functions in reaching the high school-age group.

4. The fact that 524 of 593 students replied to a question as to why the people concerned with the management of wildlife were interested in what you know, suggested a genuine interest. Their comments would enlighten many school administrators.

5. One of the real answers to the general low level of knowledge of conservation was evident in the response of county school superintendents to the initial query regarding the survey in their respective counties. Only 13 of 31 replied to the initial contact; a subsequent letter resulted in 8 more replies. This suggested that there is considerable lack of interest at the administrative level.

These data suggested that the Illinois public has reason to be alarmed about the present training of secondary pupils in conservation. However, much of this could be corrected through appropriate changes in the requirements for certification of all secondary school teachers and the redesigning of school curricula.

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PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy and one carbon copy should be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. An abstract must accompany each article. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, *Acknowledgments*, and *Literature Cited*.

No footnotes are to be used in the text.

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Illinois State Academy of Science

Volume 58
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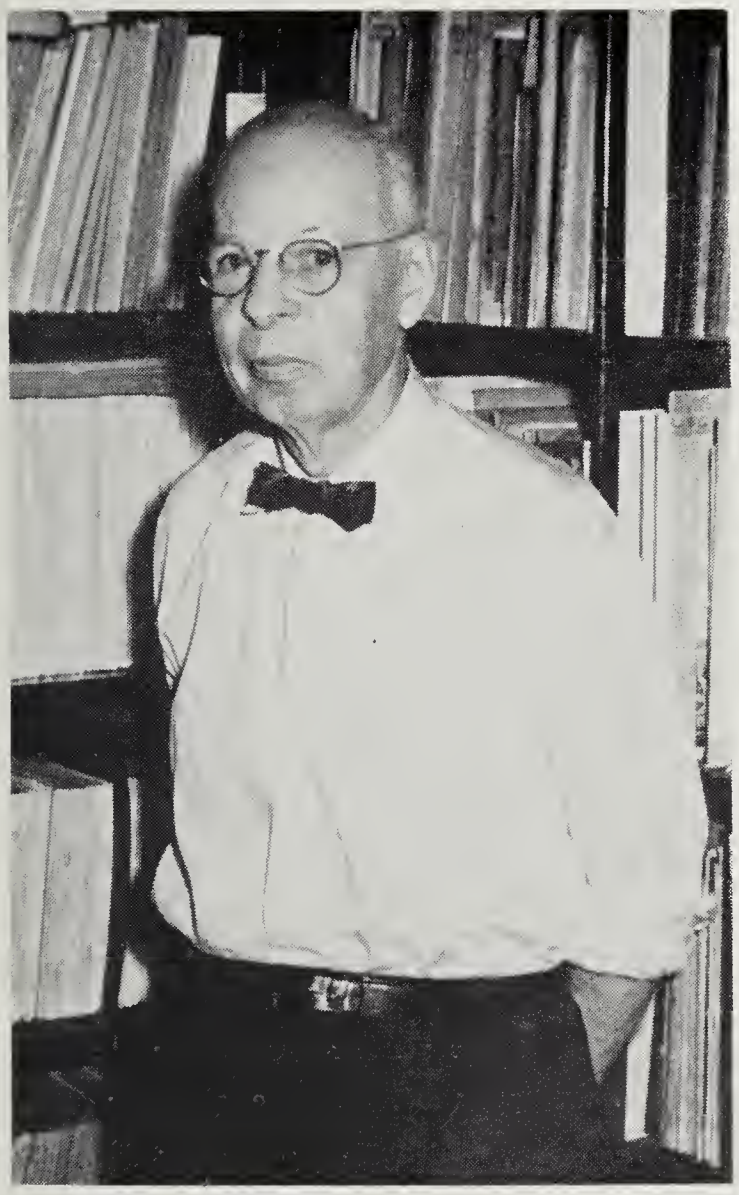
ARTHUR GIBSON VESTAL
1888 - 1964

ROBERT A. EVERS
State Natural History Survey, Urbana



ARTHUR GIBSON VESTAL 1888-1964

Arthur Gibson Vestal, professor emeritus, University of Illinois, and a long-time member of the Illinois State Academy of Science, died at 1:45 a.m., Friday, June 5, 1964, in Champaign, Illinois, at the age of 75 years, 10 months and 25 days.

Dr. Vestal was born in LaGrange, Illinois, on September 10, 1888. When he was 8 years old he went to live near Pentwater, Michigan, on the farm of his great-aunt. There he developed an interest in botany and more especially in the vegetation of dunes and bogs, an interest that continued throughout his life. At the time he had what he called "the vague notion it might be interesting to know the plants" and why some grew where they did. He moved to Chicago where he attended the public schools and graduated from high school.

Dr. Vestal attended the University of Illinois and took courses in plant and animal ecology under H. A. Gleason and Charles C. Adams. During the summer of 1909 he was employed as a botanist by the State Laboratory of Natural History, now the Illinois Natural History Survey. In 1911, he was awarded the Bachelor of Arts degree by the University of Illinois. In the same year he was appointed instructor in biology at the University of Colorado, a position he held until 1914.

At the University of Colorado, Professor Vestal became acquainted with Francis Ramaley, a "modest and great botanist and ecologist," and the "versatile" zoologist, T. D. A. Cockerell. Professor Vestal had the ambition to do the plant and animal ecology of the Great Plains but learned on a visit to H. L.

Shantz, then at Akron, Colorado, that Shantz's ambition was a regional study of the prairie regions and the Great Plains. Professor Vestal abandoned his own ambitions in this field and began a study of the eastern border of the southern Rocky Mountains, from central Wyoming into New Mexico. In his studies he "found it necessary to learn more about plants before understanding the animal part of such a study, and to learn more about physical geography and history before understanding the plant part." His field work was accomplished by "railroad, footwork, and chiefly bicycle,——." To him, the bicycle trips were the most interesting and in later years he was delighted to recount his experiences with a bicycle in the Rocky Mountains. As a result of these studies he published three papers (1914, 1917, and 1919) that remain excellent contributions to the ecology of the front range.

Professor Vestal spent the summer of 1913 at Douglas Lake in Michigan, doing quadrat studies for H. A. Gleason and correlating grasshoppers with plant communities. Also in 1913 he received a Master of Arts degree from the University of Colorado. The summer of 1914 he spent at the Montana Biological Station at Flathead Lake.

Professor Vestal attended the University of Chicago where he spent four quarters with Professor H. C. Cowles. These four quarters plus the graduate credit from the University of Colorado were sufficient for him to receive in September, 1915, the Doctor of Philosophy degree. While attending the University of Chicago he met Dr. Wanda Pfeiffer, a member of the faculty of the botany department. In 1916 they were married.

Upon completion of his doctorate, Professor Vestal went to Eastern Illinois University, succeeding E. N. Transeau. He spent five years at Charleston, during which time he developed an acquaintance with Coles and Cumberland counties and published several short papers on their ecology.

In 1920, Professor Vestal moved to California where he joined the faculty of Stanford University as assistant botanist. While at Stanford his researches centered on the relations between soils and vegetation, physical environments in forest, chaparral and grassland, and on the many types of grasslands in various sections of California. He continued his studies of the latter during summers, during leaves of absence, and after his retirement. During his years at Stanford he had an active association with F. E. Clements, the noted ecologist.

In 1929, Professor Vestal returned to the botany department of his alma mater, the University of Illinois. To him the University of Illinois had a long tradition of work in plant and animal ecology, beginning with Stephen A. Forbes. He taught a number of courses including forest ecology, plant ecology, plant geography, and plant communities. Incidental to teaching he explored the literature of ecology and regional plant geography, compiling notes and excerpts and accumulating a vast card file. Among his treasures were "expressions by old-timers of ideas recurrently discovered by present-day ecologists." Dr. Vestal had an in-

terest in poetry, especially that which touched on natural history.

In 1932 Dr. Vestal had a very interesting summer session at the University of Wyoming Biological Station. This was followed by travel and study in California. From then until his retirement from the University of Illinois, he visited the west coast at almost regular two-year intervals. During his leaves of absence in 1937, 1947, and 1955, he collected grassland plants and studied these species in herbaria at Berkeley and Stanford.

On September 1, 1957, Professor Vestal retired after 28 years of active work in the botany department of the University of Illinois. Retirement to him did not mean a cessation of activity. His interest in the vegetation of Illinois continued and he was delighted to spend time in the field. His trips to the west coast continued, as did his study of the California grasslands. His last trip to the coast was in 1963.

Upon his return from the west in the autumn of 1963, Professor Vestal showed signs of illness. In December he was first hospitalized. From that time he had periods of hospitalization until his death on June 5, 1964. Dr Vestal is survived by his widow, two sons and a daughter.

Dr. Vestal served in the botany department of the University of Illinois under three heads and two chairmen: C. F. Hottes, J. T. Buckholz, N. E. Stevens, O. Tippo, and J. R. Laughnan. During his student days in the department he was acquainted with the pioneer botanist, Dr. T. J. Burrill. He was later associated with professor-emeritus William Trelease. He knew and admired Stephen A. Forbes. He was truly a bridge between early and present botany and biology at the University.

Professor Vestal had a questioning attitude and an unwillingness to accept authoritative pronouncements by someone who attained a wide following. He "tilted a numer of windmills," among which were climate-worship with the accompanying neglect of topographic and edaphic influences; also overemphasis on climax, the faith-like belief that sufficient measurement of the physical environment will provide a sufficient explanation of the presence of a particular community, and the faith or belief that the proper plants will in time invariably arrive at and establish themselves in a particular habitat. He contributed to the ideas about communities and their enormous variabilities in composition and in abilities to adjust, to statistics of vegetation, and to more flexible ideas of succession.

Professor Vestal, as a member of the Illinois State Academy of Science, made use of the *Transactions* to publish twelve papers. One of these (1935), "A bibliography of the ecology of Illinois, Part I," has been of great value to many students of ecology in Illinois.

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1913

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In Press

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Manuscript received November 21, 1964.

THE LA SALLE ANTICLINAL BELT AND ADJACENT STRUCTURES IN EAST-CENTRAL ILLINOIS

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Illinois State Geological Survey, Urbana

ABSTRACT.—Structural development of the LaSalle Anticlinal Belt and some adjacent structures from the time of deposition of Colchester (No. 2) Coal (middle Pennsylvanian time) to the present within a five county area in east-central Illinois has been interpreted from an isopach map of the Carbondale Formation and a sequence of stratigraphic and structural cross sections.

The Colchester (No. 2) Coal, which is assumed to have been originally deposited over an essentially level surface, is now 1000 feet higher on some parts of the LaSalle Anticlinal Belt than it is in the basin part of the area. About four-fifths of the structural movement that has occurred since deposition of No. 2 Coal is believed to have taken place near the end of, or after, Pennsylvanian time.

Present structure of the Kimmswick "Trenton" Limestone (Ordovician) in the area shows that the structural movement following deposition of No. 2 Coal constitutes less than half the total movement that has occurred during the entire structural history of the LaSalle Anticlinal Belt.

The LaSalle Anticlinal Belt, one of the major structural features of Illinois, extends south-southeastward from north of LaSalle County to northeast Wabash County and from there a short distance into southwest Indiana. Its existence and general location within the several counties it traverses have long been known, and it frequently has been the subject of geologic investigation. Studies have shown it to be a complex structure that along different parts of its trend may consist of (1) a series of en echelon folds, (2) a simple asymmetrical anticline, or (3) a monocline.

Because of a cover of glacial drift and scant subsurface information along the major part of its strike, much of the detail of structure and history of development of the anticline still remains obscure. Opportunities to observe the structure in outcrop generally are limited to the vicinity of LaSalle, near its northern terminus, where the crest has been breached by the Illinois River and some of its tributaries. There Ordovician and Pennsylvanian rocks are well exposed in several places. Smaller outcrops are found in other localities, but they usually are too small to reveal much of the structure. As a consequence of this limited exposure, opportunities for detailed investigation are largely dependent upon subsurface data and methods.

The considerable amount of data from petroleum prospecting along the anticlinal belt in east-central Illinois and the existence of relatively strong folding in parts of this area make it ideal for subsurface investigation of present-day structure and structural growth.

This report is an outgrowth of more comprehensive studies of subsurface Pennsylvanian geology and

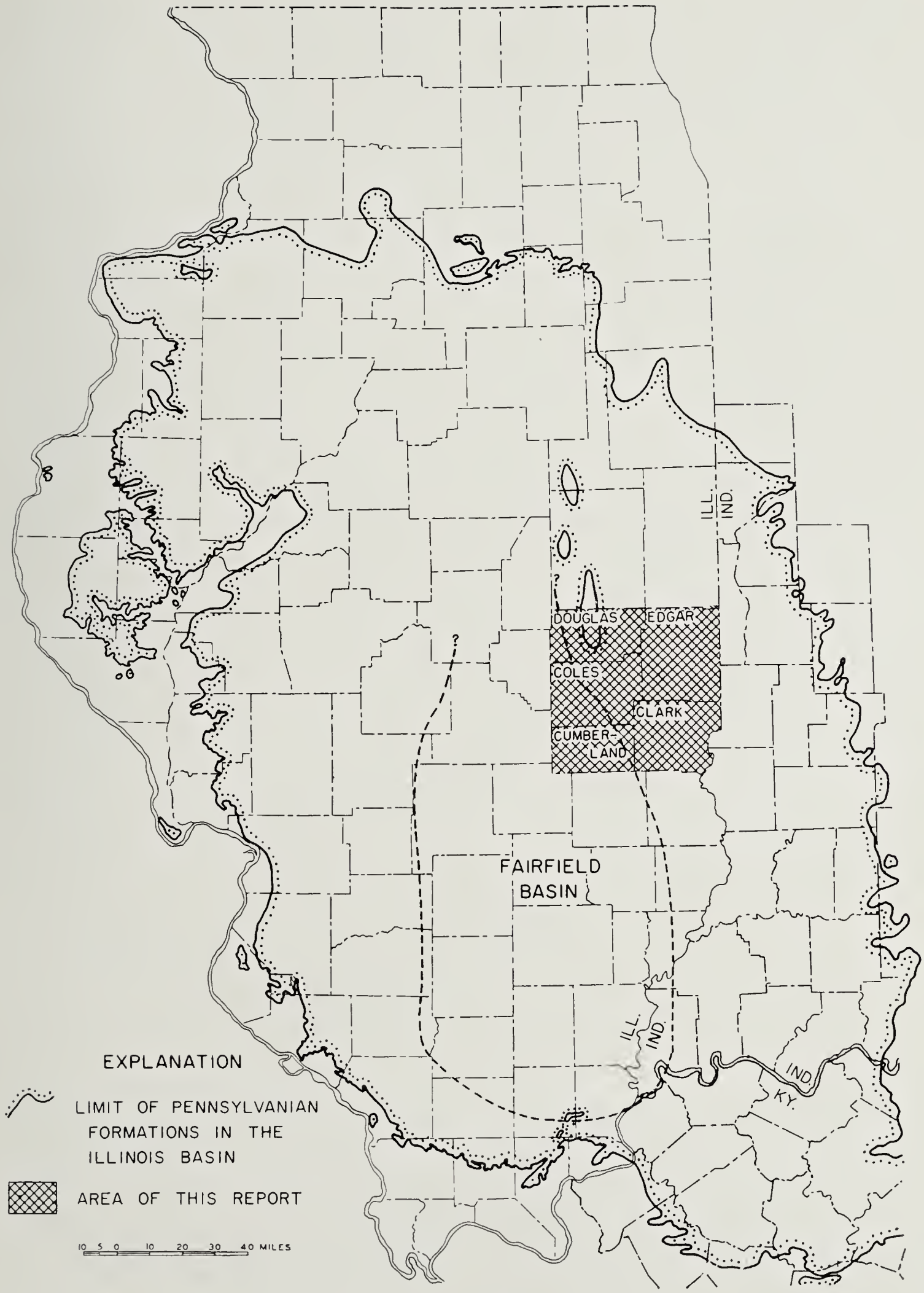

FIGURE 1. Index map showing the location of the report area relative to the Pennsylvanian boundary in the Illinois Basin and relative to the Fairfield Basin.

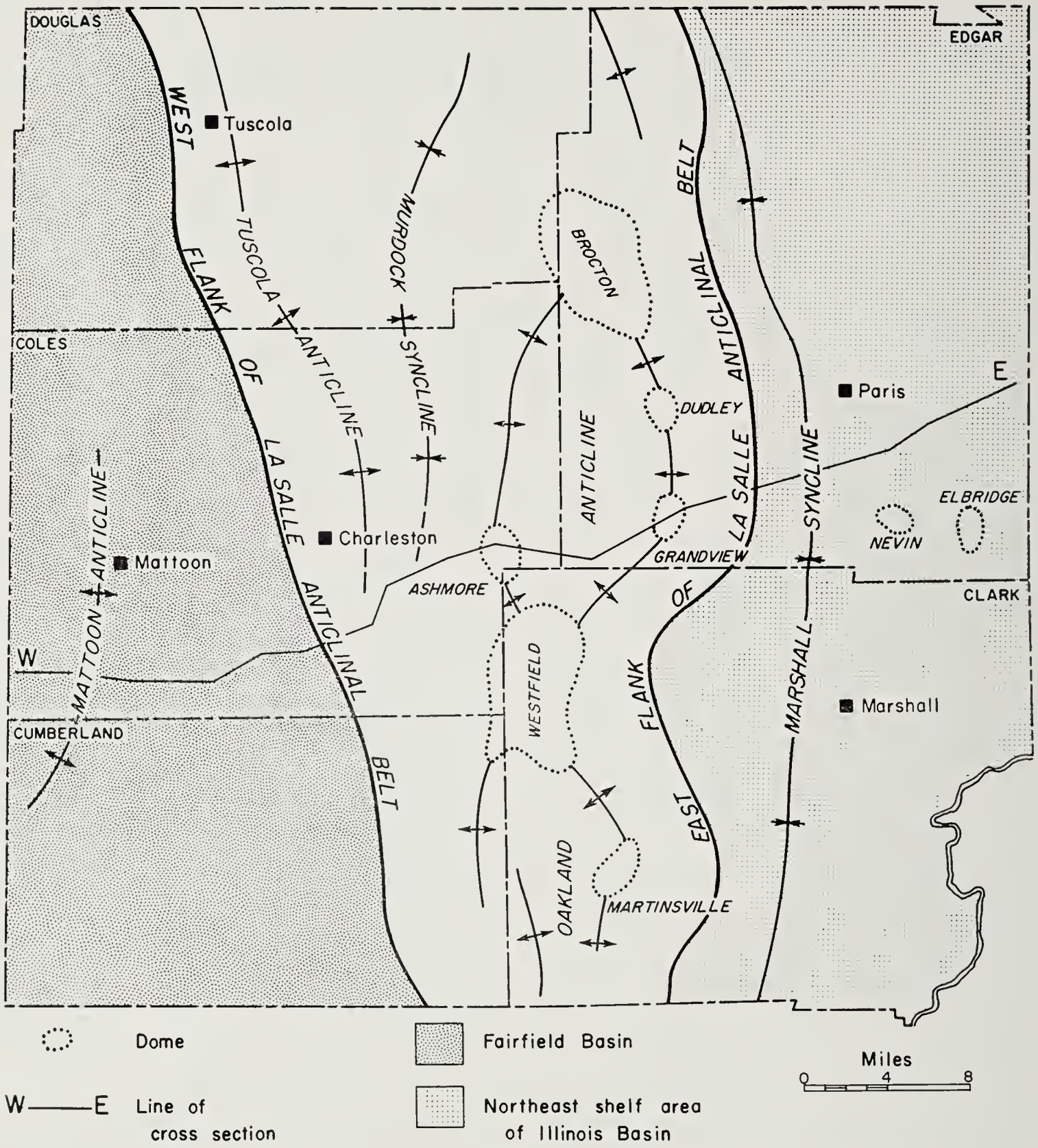

FIGURE 2. Index map of report area showing position of major structural features.

coal resources of several counties in east-central Illinois (Clegg, 1959, 1965). As the studies were concerned mainly with strata of approximately the upper half of the Pennsylvanian System, only that part of the structural development of the LaSalle Anticlinal Belt that took place after deposition of Colchester (No. 2) Coal is considered in the present report. Earlier movement involving lower Pennsylvanian and pre-Pennsylvanian strata has been reported in many publications.

GEOGRAPHIC AND GEOLOGIC SETTING

The area studied includes five counties of east-central Illinois—Cumberland, Coles, Douglas, Edgar, and Clark (Fig. 1).

Figure 2 shows the general posi-

tions and trends of fold axes. Approximately the west third of the study area is in the Fairfield Basin, which is the deeper part of the Illinois Basin. Immediately to the east is the structurally higher LaSalle Anticlinal Belt. The Marshall Syncline borders the LaSalle Anticlinal Belt on the east in Clark and Edgar Counties. Each of these three major structural divisions of the area is characterized by subsidiary anticlines, synclines, domes, and basins.

The Fairfield Basin occupies a considerable part of south-central Illinois. The largest subsidiary structure of that part of the Fairfield Basin included within the report area is the Mattoon Anticline (Fig. 2), which strikes generally north-south along the west side of northern Cumberland and southern Coles Counties. A few smaller anticlines also are present, especially in northern Coles County and in Douglas County, but for the sake of clarity they have not been shown in Figure 2. The Fairfield Basin is structurally the lowest part of the report area.

The LaSalle Anticlinal Belt occupies almost half the report area, with its west flank forming a structural divide at the edge of the Fairfield Basin in Cumberland, Coles, and Douglas Counties. It is a complex structure consisting of subsidiary anticlines and synclines and has a gentle southward plunge.

The structurally highest segment of the LaSalle Anticlinal Belt within the report area is the Tuscola Anticline, an asymmetrical, southward-plunging fold extending into the report area from the northwest part of Douglas County southeast to the vicinity of Charleston in Coles County. Throughout its length its steeper west flank coincides with the west flank of the LaSalle Anticlinal Belt. South of Charleston the LaSalle Anticlinal Belt becomes generally monoclinal, with strata dipping less steeply westward into the Fairfield Basin.

The small, gently southward-plunging Murdock Syncline lies adjacent to the east side of the Tuscola Anticline in Douglas County and northern Coles County. Limited data preclude accurate definition of the north and south ends of the Murdock Syncline. It probably loses its identity in Champaign County a few miles north of Douglas County. There is some indication that towards its south end the syncline is less prominently developed and that it may swing towards the southwest around the south end of the Tuscola Anticline to form a low cross fold in the west flank of the LaSalle Anticlinal Belt a few miles south of Charleston.

The most complex subsidiary structure of the LaSalle Anticlinal Belt in the report area is the Oakland Anticline. It is a composite structure consisting of several domes, anticlines, synclines, and poorly defined basins. Most prominent of these are the Brocton Dome in western Edgar County and the Westfield Dome in northwestern Clark County. The Oakland Anticline is an asymmetrical fold with its steeper east limb being common to the west flank of the Marshall Syncline.

The Marshall Syncline also is asymmetrical, with a comparatively steep west flank. It plunges gently southward and strikes north-south through Clark County and the south-

ern half of Edgar County, then swings slightly northwestward around the east side of the Brocton Dome. It appears to extend north of the report area at least as far as Iroquois County. South of Clark County in becomes broader and more gently dipping on both flanks, and ultimately loses its identity against what appears to be a low and irregular east-west cross fold of the LaSalle Anticlinal Belt in south-central Crawford County. The Elbridge Dome and the Nevins Dome on the east synclinal flank in southeastern Edgar County were formed by the draping of rock strata over deeply buried structures generally considered to be Silurian reefs.

Materials and Methods

Almost all of the data used in this study were obtained from records of petroleum test drilling. The most dependable and most extensively used of these were electric logs.

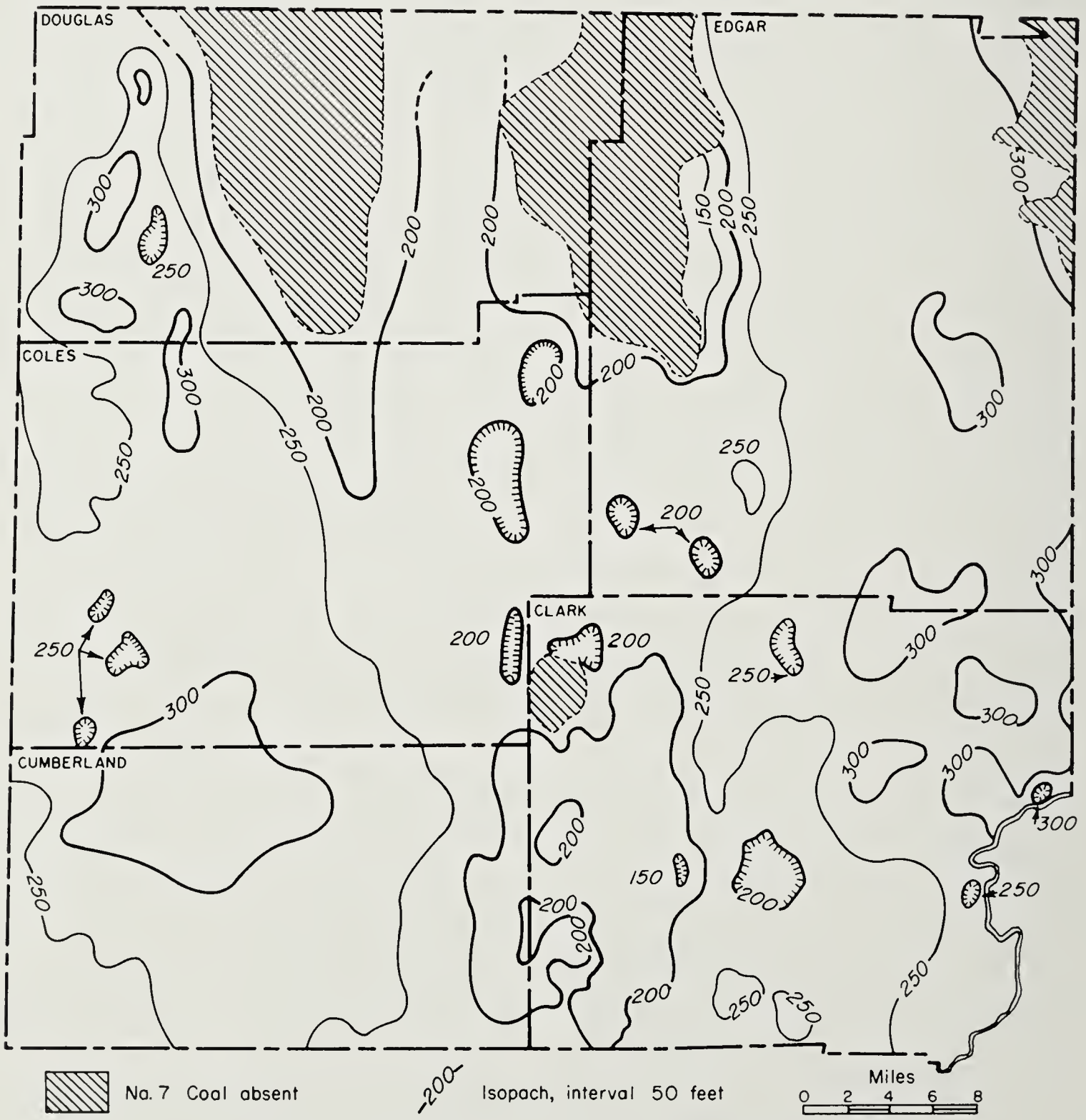

Figure 3. Isopach map of the Carbondale Formation.

The data were used to construct an isopach map (Fig. 3) and a progressively developed cross section extending east-west across the central part of the report area (Fig. 4). The map and cross section, in conjunction with structure contour maps of three Pennsylvanian coals (Clegg,

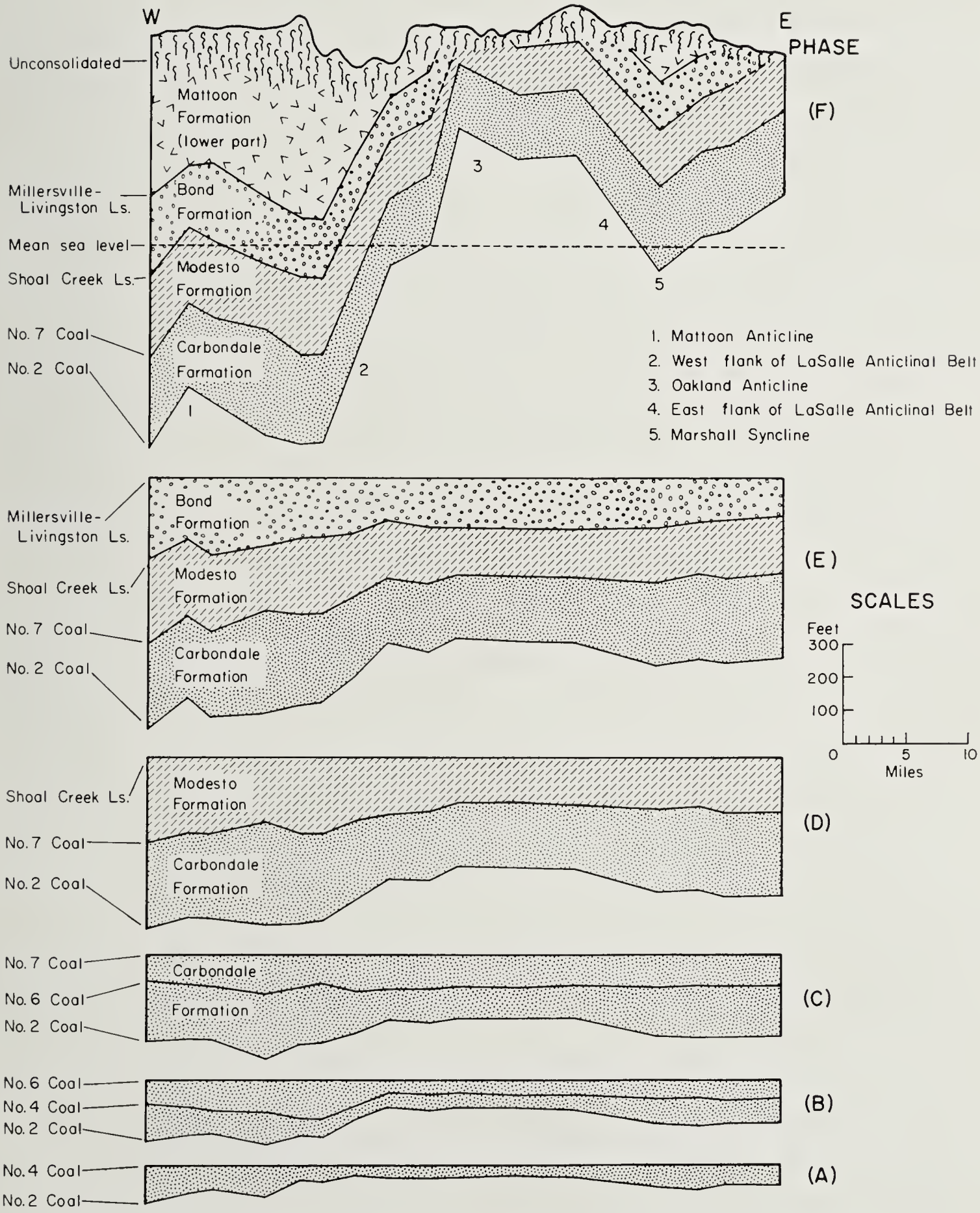

FIGURE 4. Stratigraphic and structural cross sections showing progressive development and present structure of the LaSalle Anticlinal Belt and adjacent structures in central Coles and Edgar Counties. The line of cross section is shown on Figure 2 (W-E).

1959, 1965), provide a basis for studying structural development. Hence the report is based almost entirely upon subsurface geologic materials and methods.

The lines of isopach maps connect points of equal vertical distance between two reference surfaces and thereby show any variation in thickness of the intervening strata. They also permit interpretation of the structure of the lower reference surface as it was at the time the upper was formed, thereby revealing the extent and nature of any structural movement that may have taken place within the time interval between the formation of the two surfaces. For instance, the structure of Colchester (No. 2) Coal as it was at the time Danville (No. 7) Coal was deposited can be interpreted from the isopach map (Fig. 3). The detail with which structural movement can be shown is determined by the quantity and quality of subsurface data used and the contour interval selected for mapping.

Use of isopach maps for structural interpretation necessitates, of course, the assumption that the strata involved were deposited originally over essentially flat and horizontal surfaces. Such an assumption generally is considered to be valid where Pennsylvanian limestones and coals in Illinois are concerned.

To interpret tectonic movement from isopach maps and stratigraphic cross sections the possible role played by differential compaction of sediments must be considered. The draping of Pennsylvanian strata over Silurian reefs in southeastern Edgar County is the result of differential compaction of thicker sediments in areas adjacent to the reefs. Probably some of the smaller domes of the Oakland Anticline also are due, in part at least, to differential compaction over and around sandstone bodies. In general, however, tectonic movement appears to have been the controlling factor that determined major locations and trends of the structural features in this area, with differential compaction serving only to increase the degree of structural dip.

Stratigraphic cross sections offer a somewhat more limited means of studying structural development in that they normally display conditions in one direction only, that is, along the line of the cross section. However, when supported by isopach and structure maps of the area traversed, their reliability as indicators of conditions for some distance on either side of their line of traverse is considerably enhanced. The same reasoning applies to the use of structural cross sections. As is true of isopach maps, the originally level deposition of the reference strata must be assumed and the possible role of differential compaction of sediments considered.

Inasmuch as they are supported by detailed structural maps of several coals (Clegg, 1959, 1965), the isopach map and cross section prepared for this report are considered to provide a reasonably reliable picture that may, in general, be applied to the area as a whole.

Interpretation

The Carbondale Formation includes all strata between the top of Danville (No. 7) Coal and the base of Colchester (No. 2) Coal. Al-

though the isopach interval is 50 feet (Fig. 3), the positions of all the major structural features except the Marshall Syncline can be identified on the isopach map. The Fairfield Basin is the area generally west of the 250-foot contour that extends from north-northwest to south-southeast through Douglas, Coles, and Cumberland Counties. Maximum thickness of the Carbondale Formation in this part of the Fairfield Basin is slightly more than 300 feet. The presence of relatively smaller positive structures within the Fairfield Basin, i.e., the Mattoon Anticline and other small folds north of it, is suggested by the hachured 250-foot contours. Stratigraphic thinning over these structures indicates that movement took place there during the time interval between deposition of No. 2 Coal and No. 7 Coal.

The LaSalle Anticlinal Belt, which occupies a roughly triangular area in the central part of the report area, also is readily recognizable. Here stratigraphic thickness between No. 2 and No. 7 Coals is less than 250 feet, with a minimum of slightly less than 150 feet. The positions of the Tuscola Anticline, the Murdock Syncline, and the composite Oakland Anticline, all structural elements of the LaSalle Anticlinal Belt, also are identifiable. Lesser positive structures of the Oakland Anticline are indicated by 200-foot hachured contours. As suggested previously, differential compaction of sediments around sandstone bodies within and below the Carbondale Formation may be in part responsible for minor variation in thickness of the Carbondale strata in at least some of these small areas.

Although Carbondale strata thicken east of the Oakland Anticline, there is no tendency towards general thinning east of the present position of the axis of the Marshall Syncline in Clark and Edgar Counties. The implication is that development of the east flank of the Marshall Syncline in Illinois had not begun before deposition of the Danville (No. 7) Coal was completed.

Absence of No. 7 Coal from four localities in the area (Fig. 3) is a result of post-Pennsylvanian erosion. It is significant that the Carbondale Formation is relatively thinner approaching those barren localities on the LaSalle Anticlinal Belt, indicating that during deposition of Carbondale strata the elevation of No. 2 Coal over these localized areas increased relative to that in the surrounding areas. There was no thinning of the Carbondale Formation approaching the barren area in northeast Edgar County, however, because development of the east flank of the Marshall Syncline had not begun by the time No. 7 Coal was deposited.

Depth and elevation data from sixteen electric logs were used in preparing a progressively developed stratigraphic cross section and a structural cross section from west to east across the central part of the report area (Fig. 4). The line traversed by the section is indicated in Figure 2. This line crosses the LaSalle Anticlinal Belt near the south ends of both the Tuscola Anticline and the Murdock Syncline where they are considerably less pronounced than they are farther north. Structural growth can best be followed in Figure 4 by beginning at

the bottom and progressing upward.

Phase A shows that by the time Summum (No. 4) Coal had been deposited Colchester (No. 2) Coal had already been slightly folded. Movement is reflected in the upfolding of No. 2 Coal over the Mattoon Anticline, downfolding across the Fairfield Basin, and upfolding over the general area of the LaSalle Anticlinal Belt. The crest of the Mattoon Anticline at this time was east of its present position (shown in the structural cross section, phase F) and the deepest part of the Fairfield Basin was west of its present position. There was very little difference in elevation across the entire Anticlinal Belt at that time, whereas at the present time the Oakland Anticline is considerably higher than that part of the anticlinal belt to the west. East of the Oakland Anticline the dip was gently eastward and there was no indication of an east flank to the Marshall Syncline. The very slight variation in stratigraphic thickness just east of the present location of the axis of the Marshall Syncline probably is a function of differential compaction of sediments. Minor thickness variations of this sort are present in all the succeeding phases, but as they do not occur repeatedly in the same place and do not persist for a long period of time, they probably result from differential settling rather than tectonic movement.

Phase B was constructed with the top of Herrin (No. 6) Coal as the horizontal datum and shows the structural movement that had taken place after deposition of No. 4 Coal. That there seems to have been no additional development of the Mattoon Anticline is indicated by lack of a fold at that point in No. 4 Coal. The No. 2 Coal, however, still retained essentially the same structure here that it had when No. 4 Coal was deposited.

The westward dip of No. 4 Coal on the west flank of the LaSalle Anticlinal Belt indicates continued structural movement there. This movement is also reflected in No. 2 Coal which by this time dipped somewhat more steeply than it did when No. 4 Coal was deposited.

Minor downfolding of both No. 4 and No. 2 Coals on the west side of the LaSalle Anticlinal Belt may indicate the position of the south end of the Murdock Syncline. If so, it was somewhat east of its presumed present position. However, as previously explained, the location of the south end of the Murdock Syncline is not well known.

Only minor additional folding had taken place along the west side of the Marshall Syncline after deposition of No. 4 Coal, as evidenced by the very slight eastward dip of that coal. This very slight dip could be attributed to differential compaction rather than to tectonic movement. The No. 2 Coal still retained essentially the same structural attitude that it had when No. 4 Coal was deposited. The east flank of the Marshall Syncline had not begun to develop when No. 6 Coal was deposited.

Phase C was constructed with the top of Danville (No. 7) Coal as the horizontal datum. This phase includes the same stratigraphic interval as that mapped in Figure 3, the Carbondale Formation, and shows the accumulated structural deformation that had taken place from

the time of formation of No. 2 Coal to that of No. 7 Coal. The No. 6 Coal dipped gently from the west side of the area into the Fairfield Basin and indicated that no further folding of the Mattoon Anticline had taken place since No. 6 Coal was deposited. The position of the anticline was still reflected in No. 2 Coal, however, which retained the folding it had undergone prior to deposition of No. 4 Coal.

The lowest part of the Fairfield Basin in Coles County was still west of its present position and was slightly lower structurally, as indicated by the downfolding of No. 6 Coal and by the additional downfolding of the No. 2 Coal. At the present location of the lowest part of the Fairfield Basin, No. 6 Coal was slightly higher than on either side and showed no evidence of continued folding along the west flank of the LaSalle Anticlinal Belt. The reason for the local structural high of No. 6 Coal is not clear. It may be a function of differential compaction of sediments. The vertical distance between key strata is considerably greater west of the LaSalle Anticlinal Belt, and electric logs indicate that much of the sedimentary material consists of coarse clastics. However, there do not seem to be any locally developed sandstone bodies sufficiently large to account for the amount of difference in elevation shown by No. 6 Coal. The No. 2 Coal still showed the slight downfold that may reflect the south end of the Murdock Syncline, but No. 6 Coal indicated no evidence of further development of this structure. To the east, No. 6 Coal was essentially level, indicating lack of further development of the west flank of the Marshall Syncline. However, the earlier development of this west flank was still reflected by No. 2 Coal, but neither No. 6 nor No. 2 Coal showed any evidence of the beginning of an east synclinal flank in Illinois.

Phase D was constructed with the base of the Shoal Creek Limestone as the horizontal datum. It includes the stratigraphic thickness of two formations—the Carbondale Formation (phase C) and the overlying Modesto Formation, which includes strata between the top of Danville (No. 7) Coal and the base of the Shoal Creek Limestone.

The No. 7 Coal, since its original deposition, had assumed a somewhat anomalous structural attitude west of the LaSalle Anticlinal Belt. As was suggested concerning the structure of the No. 6 Coal in phase C, the structure of No. 7 Coal may be a function of differential compaction. It reflected slight continued development of the Mattoon Anticline but stood structurally higher east of there. It was downwarped at the present position of the lowest part of the Fairfield Basin in the area and showed evidence of further folding of the west flank of the LaSalle Anticlinal Belt. It showed a slight rise at about the present position of the west flank of the Oakland Anticline, which is at the same position as the east flank of the small downfold reflected in No. 2 Coal and thought to be the south end of the Murdock Syncline. From there No. 7 Coal dipped gently eastward with a very slight upfolding, also reflected in the underlying No. 2 Coal, just east of the present axis of the Marshall Syncline. There still

was no indication of the beginning of an east flank of the Marshall Syncline when the Shoal Creek Limestone was deposited.

Phase E (fig. 4) was constructed using the Millersville - Livingston Limestone as the horizontal datum. Three formations, Carbondale, Modesto and Bond, are included, the latter consisting of strata between the base of the Shoal Creek Limestone and the top of the Millersville-Livingston Limestone. The upper limestone is known as Millersville Limestone in the Fairfield Basin and as Livingston Limestone east of the LaSalle Anticlinal Belt and in Indiana (Kosanke et al., 1960).

The Shoal Creek Limestone had, by this time, been folded over the Mattoon Anticline and from there rose gradually eastward, indicating a westward shift of the lowest part of the Fairfield Basin and continued but slight folding of the west part of the LaSalle Anticlinal Belt. It remained essentially level from there to the present position of the axis of the Marshall Syncline and showed slight upfolding of the east limb of this structure. Thus, the first indication of development of the east flank of the Marshall Syncline in Illinois did not occur until about the time the Livingston Limestone was deposited. There was no reflection of the south part of the Murdock Syncline in the structure of the Shoal Creek Limestone, nor had there been any further noticeable development of the Oakland Anticline.

Colchester No. 2 Coal reflected the continued folding of the Mattoon Anticline and the westward shift of the lowest part of the Fairfield Basin. It also showed the continued development of the west flank of the LaSalle Anticlinal Belt. The suspected position of the south end of the Murdock Syncline also was still evident in the structure of No. 2 Coal, as was the incipient east limb of the Marshall Syncline.

Phase F, showing the structure as it is at the present time, also shows that the folding that took place following deposition of the Millersville-Livingston Limestone was greater than the total folding that had taken place between the time of deposition of No. 2 Coal and that of the Millersville - Livingston Limestone. The amount of folding that occurred between deposition of No. 2 Coal and the Millersville-Livingston Limestone is noticeably less than that following deposition of the limestone. At the time of formation of the limestone, No. 2 Coal was only 200 feet higher on top of the LaSalle Anticlinal Belt where that structure is traversed by the cross section than it was in the Fairfield Basin. At the present time the elevation difference, measured at the same places, is 1000 feet, indicating that after deposition of the Millersville Limestone the elevation of No. 2 Coal on the LaSalle Anticlinal Belt had increased 800 feet relative to its elevation in the Fairfield Basin.

The Oakland Anticline had its maximum development during the late stages of folding and now stands considerably higher than the rest of the LaSalle Anticlinal Belt in this part of the report area. The two high points of the anticline (fig. 4) are near the tops of the Ashmore and Dudley Domes. The top of the anticline is somewhat lower between these two subsidiary structures.

The Tuscola Anticline, which is too far north to be reflected in the cross section, currently is the structurally highest feature of the LaSalle Anticlinal Belt in the report area. Its structure, based upon contour maps of three coals (Clegg, 1959), indicates that it, too, underwent considerable deformation during the late stages of tectonic development, i.e., after deposition of the Millersville Limestone.

The Murdock Syncline is not depicted in the structural cross section. Whether the slight downfolding shown in the stratigraphic section is actually a reflection of earlier stages in the development of the Murdock Syncline is conjectural. It is possible that the syncline had its inception prior to deposition of the Millersville Limestone and that subsequent folding deepened the structure farther to the north while at the same time the south end was tilted towards the west. The position of the Oakland Anticline adjacent to the south end of the Murdock Syncline is such that tilting and concurrent westward shifting of the syncline's axis could have occurred as the south part of the Oakland Anticline attained its present relative structural elevation.

The above suggestion is offered in support of the previous suggestion that towards its southern end the Murdock Syncline may swing westward around the south end of the Tuscola Anticline. Until more information is available, however, the position of the southern part of the Murdock Syncline remains unknown. It is possible that it never extended farther south than the vicinity of Charleston or that it originally extended farther southward but that the southern extremity was obliterated during the last stages of tectonic activity.

That the present structure of the Marshall Syncline in Illinois developed almost entirely after deposition of the Livingston Limestone is indicated in the structural cross section. Incipient development of the east limb as noted in phase E, had begun when the Livingstone Limestone was deposited, but full development came later. The exact time of the last stages of tectonic activity is not known. In other parts of Illinois, Pennsylvanian strata younger than the Millersville-Livingston Limestone are structurally deformed, suggesting that most of the movement came about near the end of or, more likely, following the close of the Pennsylvanian Period.

Summary and Conclusions

The structural development described includes only a small part of the total tectonic history of the LaSalle Anticlinal Belt and adjacent structures. Formation of the LaSalle Anticlinal Belt originally began at least as early as Ordovician time. It appears to have developed slowly until the end of Mississippian time. Siever (1951) showed that in counties south of the study area a period of strong folding occurred following Mississippian sedimentation. This was followed by a long period of subaerial erosion and peneplanation of the area. He indicated that a second uplift occurred after peneplanation followed by a cycle of erosion that resulted in the incision of deep channels in the peneplain surface. It was upon this incised surface that detritus from the Ap-

palachian geosyncline and some locally derived sediment were deposited. These sediments filled the channels, buried the hills, and ushered in Caseyville deposition. Available records show that the area of this report underwent the same structural and erosional history as did the counties to the south.

By the time of deposition of the first strata of the Carbondale Formation, the erosional irregularities had been deeply buried and No. 2 Coal was laid down over an essentially level surface and hence reflected none of the earlier folding.

The top of the Kimmswick "Trenton" Limestone is 4000 feet below sea level in the Fairfield Basin and about 1,500 feet below sea level on the Ashmore Dome of the Oakland Anticline, a difference of 2500 feet. As No. 2 Coal at the same localities has been shown to have a difference of only 1000 feet in elevation, it is evident that the structural movement that followed deposition of No. 2 Coal constitutes less than half of the total movement that has taken place.

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TAXONOMIC SUMMARY OF INORGANIC PROTECTIVE OR SUPPORTING STRUCTURES PRECIPITATED BY ANIMALS AND PLANTS

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ABSTRACT.—The lower plants and animals (the broad group algae in the plants and the Protozoa among the animals) are the more heterogeneous as far as inorganic protective or supporting materials are concerned. The only exception to this is the restriction of calcium phosphate to some eumetazoans. The three main types of inorganic hard parts found in animals—calcium carbonate, the calcium phosphates, and opaline silica—are all first found in the skeletons of Early Cambrian marine invertebrates, and even the organic substance chitin is present in the skeletons of some of these animals at that time. However, this pattern of early rapid differentiation does not occur in the plant kingdom. Calcium carbonate deposition occurred in some algae well back into the Precambrian. The ability of plants to deposit opal in their tissues may not have occurred before Jurassic time with the advent of the first few diatoms.

A considerable body of scattered literature has been written about the inorganic compounds which are present in the hard parts of plants and animals. Most of it is factual with generally little attempt to interpret the data biologically. (That is our main purpose herein.) Some of the facts have been repeated in several places with little or no documentation, and some of the basic data need to be reinvestigated for accuracy.

No attempt will be made to include foreign particles which some animals pick off the ocean bottom and cement to their shells, nor, as the title implies, will organic skeletal substances be included. Minor amounts of compounds, that is, those making up 20 per cent or less of the composition of the hard parts, will be ignored. With these restrictions adhered to, it is amazing to see how little variation there is in both animal and plant kingdoms as to the kinds of inorganic compounds secreted for exo- and endo-skeletal material as well as protective and supporting structures. This is true of both fossil and living groups of organisms. At the present state of our knowledge, this short review will, of necessity, pose more questions than can be answered. It is hoped that many of these questions can be answered by more observations and research on this most interesting subject.

For the invertebrate animals, most of the basic data can be found in general systematic paleontology textbooks as, for example, Moore, Lalicker, and Fischer, 1952; and Shrock and Twenhofel, 1953.

IN THE ANIMALS

Among the animals, the most singular feature is the preponderance of calcium in their skeletons, primarily as calcium carbonate but also importantly as calcium phosphate.

No distinction will be made between calcite and aragonite in this

brief survey, although calcite is generally more common and some animals, e.g. many gastropods and pelecypods, have both calcite and aragonite in their shells. Calcite and aragonite can be deposited by marine animals and plants in temperatures ranging from about —2°C to 40°C. Calcium is fairly abundant in sea water, often more so in freshwater and soils. Calcite and aragonite are not readily soluble in water of neutral pH. All of these factors help to explain why calcite and aragonite are so common in animals and the lower plants. Members of the following groups of animals, all or in part, have calcium carbonate in their exo- or endo-skeletons: Protozoa, Porifera, Coelenterata, Pleospongia, Receptaculitida, Stromatoporoidea, Labechioidea, Sphaeractinoidea, Nidulitida, Bryozoa, Brachiopoda, Annelida, Mollusca, Echinodermata, and Arthropoda. Some of these named groups are extinct, and many of these groups have large numbers of both extinct and extant species.

The second most widespread inorganic material in the skeletons of animals is some of the minerals of the apatite group. This is primarily calcium phosphate, but fluorapatite, hydroxylapatite, or carbonate-apatite occurs in some animal skeletons. Among the animals having this skeletal composition are the extinct conulariids and conodonts, some of the brachiopods and arthropods, and of course the vertebrates. One sees, however, that calcium phosphate is much less common than calcium carbonate as a skeletal material among animals, and for some reason it is confined to higher animals—the Eumetazoa. Does this indicate a phylogenetic homogeneity for the Eumetazoa? It is interesting to note, also, that calcium phosphate as a primary skeletal material appears to be completely absent in the plant kingdom.

The next most commonly occurring mineral found in animal skeletons is opal ($SiO_2.nH_2O$). It is found in some Protozoa (nearly all radiolarians) and is common in the Porifera. It has been reported in annelid worm jaws (scolecodonts). Spicules of silica are said by Nicol (1960, p. 650) to occur in the tissues of a few mollusks, and Prosser and Brown (1961, p. 72) report silica in some bryozoan skeletons.

These latter three occurrences are the only mention of silica in higher animals, and it does not comprise the main portion of the skeleton. This leads us to a most puzzling question—why do the higher animals, those above the sponges, not use silica as a main skeletal material? Again, does this indicate a phylogenetic homogeneity for the Eumetazoa?

Among the Protozoa there are a few exceptional cases in which sulphates are deposited. One small group of living radiolarians uses strontium sulphate, celestite, as a skeletal material. This occurrence is well documented and has been known for some time. One deep-sea group of rhizopods is reported by Prosser and Brown (1961, p. 72) to have a skeleton in which the inorganic part is made up of barium sulphate (barite). This latter occurrence is not well documented, and it exhausts the relatively small list of inorganic skeletal compounds found among animals.

In the Plants

The two inorganic materials most commonly deposited by plants are calcium carbonate and opaline silica. In the case of calcium carbonate, the mineral in a given species is either calcite or aragonite. This is unlike some animals in which both may be present. Information concerning the distribution of calcite and aragonite in numerous plants may be found in the papers by Lewin (1962), Lowenstam (1954), and Vinogradov (1953).

Silica is usually present as hydrated or opaline silica; however, quartz is produced in some diatoms and in the flowering plant *Ficus*, according to Roelofsen, 1959.

In addition to the inorganic materials previously mentioned as occuring in plants, a few instances of $Fe(OH)_3$ and $Mn(OH)_3$ deposition are known which appear to be a facultative feature of the physiology of the plants involved.

Inorganic cell inclusions are generally omitted from the present summary with the exception of a few examples such as the occurrence of opal in elements of wood and the occurrence of calcium carbonate in epidermal cells.

Among the various groups of algae, calcium carbonate deposition is much more widespread than is the deposition of silica. In the case of the vascular plants the two compounds are apparently about equal in occurrence.

Calcium carbonate is deposited in large amounts in the algae, including members of the Chlorophyta, Cyanophyta, Rhodophyta, Phaeophyta, and Charophyta. Among the fungi the best documented and studied case of calcium carbonate deposition occurs in the Myxomycophyta (slime molds and related forms), where the two orders Physarales and Stemonitales are partially distinguished from other orders by the presence and distribution of calcium carbonate in the fruiting structure (Alexopoulos, 1952).

It is of some interest to note that in the green algae the deposition of calcium carbonate is confined to those forms which are on the siphonine path of evolution: the orders Siphonales and Siphonocladiales. The charophytes are known to deposit calcium carbonate in both the vegetative and reproductive portions of the plant body. Large amounts of calcium carbonate in the oogonial structure probably account for the relative abundance of oogonial remains in the fossil record.

Among the blue-green algae (Cyanophyta) calcification occurs most commonly in those forms which are found in geyser pools and other bodies of relatively warm water. There appears to be no systematic pattern of calcium deposition among the taxonomic groups of the Cyanophyta; however, the following genera are important depositers of calcium carbonate: *Anabaena*, *Aphanothece*, *Chamaesiphon*, *Lithomyxa*, *Lyngbya*, *Microcoleus*, *Paracapsa*, *Petaloma*, *Phormidium*, *Rivularia*, and *Schizothrix*.

The so-called coralline red algae (Rhodophyta) are conspicuous in the formation of reefs and are for the most part members of the Cryptonemiales. These forms have a prominent fossil record. In the Nemalionales the genus *Liagora* also produces calcium carbonate, which in this case

is laid down about a much simpler thallus than is the case in the cryptonemialean forms.

Only one genus of brown algae (Phaeophyta) is known to produce calcium carbonate in any large amount. This is the genus *Padina*, which is otherwise a typical member of the order Dictyotales (Fritsch, 1945). There appears to be no systematic significance to this isolated instance of calcium carbonate deposition by *Padina*.

Deposition of calcium carbonate is known to occur in the flowering plants in the families Curcurbitaceae, Cruciferae, Boraginaceae, Loasaceae, Acanthaceae, Urticaceae, Combretaceae, Moraceae, Gesneriaceae, Geraniaceae, and Cistaceae (Frey-Wyssling, 1959; Roelofsen, 1959; Uphof, 1962). This calcification occurs in epidermal cell walls, in epidermal trichomes, and in special cells of the epidermis (so-called lithocysts).

The silicification of cell walls is best known in diatoms, where it has been studied in most detail. Lewin (1962) has recently reviewed the current state of understanding of the structure of diatom walls and the physiological processes involved in silicification. In addition to diatoms, other members of the Chrysophyta are known to produce siliceous deposits in cell walls. Typically, resting spores of golden algae (class Chrysophyceae), which are sometimes referred to as statospores, have a highly silicified wall. The literature contains reports of the occurrence of silica in the cell walls of vegetative parts of some yellow-green algae (class Xanthophyceae); however, these plants have not been studied in this respect in recent years (Smith, 1955). Phycologists such as Smith have placed great significance upon the silica-metabolizing ability of the forms in the division Chrysophyta, and this feature seems to be an important one which unites the members of the three classes included in the division. Indeed, on the basis of their ability to metabolize silica, it has been suggested that the members of this division be grouped with the Choanoflagellata, Porifera, and Sarcodina into a distinct kingdom, the Silicobiota.

In vascular plants, silicification occurs in widely divergent groups: the Equisetales, which is the sole extant order of the subphylum Sphenopsida, and the class Angiospermae of the subphylum Pteropsida. In the equisetalean genus *Equisetum*, silica is deposited in the epidermal cells and forms a thick layer on the outer cell wall. Among the angiosperms, silica is deposited both in cell walls of the epidermis and within special cells of the epidermis in numerous members of the family Gramineae (grasses). In the latter instance, highly opaline silica fills the cell lumen (Esau, 1953). Among the flowering plants, silica is also found in numerous species of various taxonomic groups primarily in cells of the secondary xylem. Over four hundred timbers are listed by Amos (1952) as having siliceous cell inclusions, primarily within cells of the vascular rays. This appears to be almost pure SiO_2 and forms a vitreous layer in vessels and some other elements of wood in addition to the vascular rays. Silica is also reported as occurring in the later-formed walls of endodermal

cells of *Andropogon* (Borissow, cited in Frey-Wyssling, 1959) and in hairs of members of the families Campanulaceae, Moraceae, Ulmaceae, Urticaceae, Primulaceae, Loasaceae, Crassulaceae, Compositae, Leguminosae, Haloragidaceae, and Verbenaceae. Although silicification seems to be characteristic of many members of some angiosperm families such as the Moraceae and Urticaceae, its generally scattered occurrence suggests that it does not have any special significance in determining phylogenetic relationships among the angiosperms. Both Netolitzky (1929) and Frey-Wyssling (1959) have suggested that silicification of plant parts is correlated with a warm climate in which silica would be expected to be more readily available for uptake by the plants. It is not known whether the deposition of silicates on the plant surface of submerged forms or that of iron and manganese in the cases cited here is simply accretion of the mineral or is due to an active uptake of the materials and subsequent deposition by the plant cells.

In a few cases plants are known to deposit iron and manganese in an inorganic form. Euglenoids and desmids are the most outstanding examples of this occurrence of iron and manganese, which appears to be present as $Fe(OH)_3$ and $Mn(OH)_3$ respectively (Roelofsen, 1959). In some green algae such as *Oedogonium* and *Cladophora*, the deposit of iron-containing inorganic matter forms a crystalline incrustation about the plant body. Literature cited by Frey-Wyssling suggests that the deposition of both iron and manganese hydroxides is facultative and occurs when large amounts of those two elements are present in the plant's environment.

Remarks

It is apparent that the lower plants and animals (the broad group algae in the plants and the Protozoa among the animals) are the more heterogeneous as far as inorganic skeletal materials are concerned. The only exception to this is the restriction of calcium phosphate to some eumetazoans. This seems to support the opinion that the lower animals and plants may have had a polyphyletic origin.

The three main types of inorganic hard parts found in animals — calcium carbonate, the calcium phosphates, and opal — all are found in the skeletons of Early Cambrian marine invertebrates. This has also been pointed out in a recent paper by Lowenstam (1964, p. 172). It should be added that even the organic substance chitin also occurred in some Early Cambrian invertebrate skeletons. Does this indicate little change in the chemical composition of sea water since Early Cambrian time? Here again is another example of early primary diversity or differentiation in the various major animal groups. Only minor or relatively little differentiation has appeared in major animal groups, as concerns the inorganic hard parts, since Early Cambrian time. However, this pattern of differentiation does not occur in the plant kingdom. Calcium carbonate deposition apparently arose early in the evolution of the plant kingdom, and algal limestones are known which extend

well back into the Precambrian, possibly as long as 2.5 billion years ago. On the other hand, the ability of plants to deposit opal in their tissues appears to have been acquired quite late in geologic time. There is as yet no known fossil record of siliceous plants before the first few diatoms of the Jurassic, which was certainly less than 175 million years ago.

Thus we see that the number of inorganic compounds and minerals utilized by both animals and plants are amazingly few. The minerals commonly involved are calcite, aragonite, the apatite group, and opal. For all organisms, calcium carbonate is certainly the most common skeletal compound. Because of the plants, opaline silica must be ranked second most widespread, followed by the various calcium phosphates. Silica, iron hydroxide, and manganese hydroxide among the plants, and strontium sulphate and barium sulphate among the animals, are all generally rare and exceptional. Does this indicate a close phylogenetic relationship for all organisms? Because of the rarity of the elements involved, varying degrees of solubility in water, temperature of formation of the mineral (usually above that of ordinary temperatures found in the sea or on land), or some other adverse factors, the minerals present in animal or plant protective or supporting structures are perhaps about the only ones which the animals or plants could possibly find available. In other words, the minerals found in plant and animal skeletons probably represent the least soluble compounds which the animal or plant can synthesize from the elements which are available in sufficient concentrations. However, if we think of all of the minerals in sedimentary rocks, those formed at ordinary temperatures and pressures, some being quite common, we wonder why animals and plants have not used many of them as skeletal or supportive materials.

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EFFECTS OF BURNING AND FALLOWING ON VEGETATION

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ABSTRACT.—During 1954 and 1955 a study of the effects of burning and fallowing on idle land was conducted on property of the United Electric Coal Companies, Inc. near DuQuoin, Illinois. The plant families Rubiaceae, Gramineae, Juncaceae, and Polygonaceae decreased in number as a result of burning; increases were recorded for the Compositae, Euphorbiaceae, and Leguminosae. Plants showing major increases were lanceleaf ragweed, *Ambrosia bidentata*, three-seeded mercury, *Acalypha virginica*, wild beans, *Strophostyles* spp., annual lespedezas, *Lespedeza* spp., and panic grasses, *Panicum* spp.; decreases were recorded for buttonweed, *Diodia teres*, rush, *Juncus* spp., sheep sorrel, *Rumex acetosella*, perennial rye grass, *Lolium perenne*, goldenrods, *Solidago* spp., and broomsedge, *Andropogon virginicus*. Bare ground was increased about 8 times and soil pH was changed from 6.9 to 7.4. Fallowing resulted in an increase in Gramineae, Rubiaceae, Rosaceae, Solanaceae, and Aizoaceae; decreases were noted for the Compositae, Euphorbiaceae, Juncaceae, and Leguminoseae. Bare ground was increased 14 times; the soil pH was unchanged. Burning and fallowing resulted in diversified habitats suitable for optimum quail utilization.

From accumulated knowledge of wildlife management there has evolved a relatively basic theory regarding availability of game. Stocking game on land that could normally support only what was already present was not the answer. Improving the habitat, and thereby increasing the carrying capacity of the land has become a fundamental concept in game management. An investigation to evaluate the effects of burning and fallowing on the vegetation, and to determine if these management techniques would be effective in establishing an environment more suitable to the bobwhite quail, *Colinus virginianus*, was prompted by this need for habitat improvement.

THE STUDY AREA

These studies were conducted on non-agricultural lands of the Fidelity Mine, a holding of the United Electric Coal Companies, Inc. located in Perry County just west of DuQuoin, Illinois. The topography of this 1200-acre area is level to gently sloping. The soil type is primarily Wynoose silt loam which is characterized by an impervious subsoil which results in little or no internal drainage (Wascher *et. al.* 1950). The limited topsoil is fine in texture with low water-holding capacity; natural fertility is poor, being deficient in calcium, potash, phosphorus, nitrogen, and organic matter. Many small gullies and outwashes have developed on the slopes.

Open fields and woodlots characterize this non-agricultural acreage. The fields, ranging in size from 3 to 20 acres, represent land that has been out of cultivation for 10 to 15 years. The woodlots of 5 to 140 acres in size were lightly to heavily cutover 15 or more years ago and

show dense to sparse stands of largely third-growth trees. At least four home sites, as evidenced by wells, vegetation and basements, once were located in this area. An old roadway bisects the area from east to west. On the east and north, the area is bordered by inter-tilled farmland, on the south, by pastures and on the west, by spoilbanks.

As management practices were restricted to idle fields, general descriptions are limited to these areas. These fields had been farmed previously for the production of corn and small grains; and, it seemed apparent that a suitable plan of crop rotation or soil improvement practices was not followed. The smaller fields, located on slopes, were released from agricultural use before the more level larger fields as evidenced by the stage of plant succession.

All fields, but especially the smaller ones, were being invaded by several trees and shrubs including persimmon, *Diospyros virginiana,* sassafras, *Sassafras albidum*, oaks, *Quercus* spp., wild plum, *Prunus americana,* wild black cherry, *Prunus serotina,* elm, *Elmus americana*, hawthorn, *Crataegus crusgalli,* dewberry, *Rubus flagellaris,* blackberry, *Rubus frondosus*, and trumpet creeper, *Campsis radicans*. The larger fields showed widely distributed trees and patches of shrubs whereas the small fields exhibited a uniform distribution of these woody species. The several drainage ways showed more mature trees of the above species as well as river birch, *Betula nigra*, sycamore, *Platanus occidentalis*, willow, *Salix nigra*, and red cedar, *Juniperus virginiana*.

The herbaceous vegetation was characteristic of idle fields of southern Illinois which are low in their natural fertility. Extensive stands of broomsedge and many herbs and grasses of which lanceleaf ragweed, goldenrod, aster, *Aster* spp., buttonweed, three-seeded mercury, and broomsedge were the most common. Occurring in isolated patches where competition and soil conditions were suitable were partridge pea, *Cassia fasciculata,* rushfoil, *Crotonopsis elliptica,* sheep sorrel, lespedezas, wild beans, desmodiums, *Desmodium* spp., and beggar-ticks, *Bidens* spp. Widely dispersed were such grasses as panic, three-awned, *Aristida* spp., cheat, *Bromus secalinus* and *tectorum*, and foxtails, *Setaria* spp. Except for the severely eroded slopes these herbs and grasses exhibited in autumn dense stands of vegetation 2 to 3 feet in height. They revealed heavy accumulations of dead plant materials of 6 to 8 inches on the surface of the soil. Exceptions to this were the eroded slopes where there was little vegetation other than mosses and lichens. The general appearance, from the standpoint of habitat for upland game, was one of unproductiveness because of heavy uniform cover, little natural food, and uniformity of plant species. The low populations of quail and cottontails were a direct reflection of these vegetational characteristics.

Techniques

To improve this environment for the bobwhite quail, various management practices were employed. These included controlled burning, fallowing, food-patch plantings, patch-type farming, release cutting in fence

rows, and release of pen-reared bobwhites. As this paper relates only to burning and fallowing, the techniques presented reflect these two practices.

Burning.—Techniques of burning were similar to those previously reported (Stoddard 1941; Rosene 1955; Lehmann 1937; and Lay 1954) except for time of year and amount of area burned in any one year. Controlled burning was begun in late March in 1954 and early April in 1955 and continued intermittently until the first of May. Because of extremely dry conditions, especially in 1954, the burn was not as desired, being intense and having to be controlled by fire breaks. Most burning was during early morning hours (7 to 10 AM) as fires required attendance and could be conducted only when wind movement was low. Only the open fields were included as it was too dangerous to burn woodland. To protect desirable clumps of woody vegetation, these were isolated with plowed fire lanes. Approximately one-third of the open field acreage was burned each year.

Fallowing.—Approximately 55 fallowed strips were prepared in March, April, and May in both years of the study. These strips were 5 to 15 feet wide and 100 to 1500 feet long. The strips were made through various types of herbaceous cover, and included virtually all the prevailing soil conditions. Many of the fallow patches were the plowed strips necessary to control the burning, or the unplanted one-half of food strips prepared for production of annual foods.

Sampling.—In August, 1954, and July and August, 1955, an ecological study was conducted to determine the effects of burning and fallowing on the natural vegetation. Square meter quadrats (one-quarter milliacre), used in sampling the vegetation, were located at random in unburned, burned and fallowed areas. The samples were established as parts of transects, two or more in a line, or at widely scattered points. A total of 567 quadrats were studied during the 2 years. Plant composition, plant density, the per cent bare ground, average height of vegetation and soil pH were determined in each sample. Plant density was based upon the number of individual plants of each species and not number of stems. Bare ground estimates were established on the presence or absence of vegetation covering the ground when quadrats were viewed from above. The hydronium ion activity was obtained through the use of the La Motte soil testing set.

Adequacy of sample was determined largely by a noted decrease in new species as additional samples were taken. Due to the homogeneity of many sample areas, additional quadrats merely reflected the analysis of previous samples. This marked decrease was also reflected in the "S" curve when species were plotted against samples. Per cent composition of each species of plant was determined for each area and as a total for each type of managed or unmanaged area being analyzed. This was accomplished by dividing the number of individual species by the total number of individuals recorded.

Presentation of Data

In an effort to evaluate management techniques, data from 1954 and 1955 samples were combined and analyzed. Thirty-seven families of plants representing 126 species were recorded during the 2 years of the study; included were 66 perennials, 52 annuals, and 8 biennials. Twenty-nine exotic species, mainly of European and Asian origins, were noted. Only 27 species and 11 families yielded one per cent or more of the total plant composition in one or more of the areas investigated (unmanaged, burned, and fallowed).

Unmanaged Areas.—Two hundred and thirteen quadrats established in the unmanaged areas yielded 30 plant families representing 91 species. Seven families, Gramineae (33.1%), Rubiaceae (20.1%), Compositae (16.7%), Euphorbiaceae (8.5%), Juncaceae (6.4%), Polygonaceae (5.3%), and Leguminosae (5.2%), comprised over 95 per cent of the plant composition (Table 1).

Gramineae, the most well represented family, consisted mainly of three-awned grasses (6.3%); cheat (6.2%), panic grass (5.5%), perennial rye grass (5.1%), and broomsedge (3.5%) (Table 2).

TABLE 1.—Per cent Composition of Major Plant Families on Unmanaged, Burned, and Fallowed Areas for 1954 and 1955, United Electric Coal Companies, Inc., Du Quoin, Illinois.

Plant Families	Unmanaged Areas			Burned Areas				Fallowed Areas		
	1954-55 Combined	1954	1955	1954-55 Combined	1954	1955	1954 Sampled in '55	1954-55 Combined	1954	1955
Gramineae	33.1	28.6	41.0	22.3	19.2	26.5	46.7	38.9	46.8	35.7
Rubiaceae	20.1	13.4	30.0	17.5	8.1	23.5	12.1	35.9	20.1	42.5
Compositae	16.7	23.9	4.9	21.2	35.6	11.7	10.0	3.1	4.8	2.5
Euphorbiaceae	8.5	10.1	6.2	12.6	15.5	10.8	4.6	1.3	1.4	1.2
Juncaceae	6.4	8.3	T[1]	2.9	2.4	T	T	T	T	T
Polygonaceae	5.3	5.1	5.6	4.5	3.9	4.9	12.0	5.4	2.6	6.5
Leguminosae	5.2	6.2	3.8	12.8	8.6	15.5	9.9	3.1	3.9	2.7
Rosaceae	T	T	T	T	T	T	T	1.8	T	T
Solanaceae	T	T	T	T	T	T	T	1.9	T	T
Labiatae	T	T	T	1.1	T	T	T	T	T	T
Aizoaceae	T	T	T	T	T	T	T	4.6	10.3	2.2

[1] Trace—less than one per cent.

TABLE 2. — Per cent Composition of Major Plant Species on Unmanaged, Burned, and Fallowed Areas for 1954 and 1955, United Electric Coal Companies, Du Quoin, Illinois.

Species	Unmanaged	Burned	Fallowed
Buttonweed *Diodia teres*[1]	20.1	17.5	36.0
Lanceleaf ragweed *Ambrosia bidentata*	8.7	13.9	1.4
Three-seeded mercury *Acalypha virginica*	6.6	9.8	0.7
Rushes *Juncus* spp.	6.4	2.9	0.9
Three-awned grasses *Aristida* spp.	6.3	7.7	0.2
Cheat *Bromus secalinus*	6.2	2.5	0.4
Panic grass *Panicum lanuginosum*	5.5	7.4	8.8
Sheep sorrel and dock *Rumex* spp.	5.1	4.5	5.1
Perennial rye grass *Lolium perenne*	5.1	0.6	0.1
Goldenrod *Solidago* spp.	4.2	1.8	0.5
Broomsedge *Andropogon virginicus*	3.5	1.9	2.7
Wild beans *Strophostyles* spp.	2.0	2.3	1.7
Rushfoil *Crotonopsis elliptica*	1.5	2.5	0.2
Partridge pea *Cassia fasciculata*	1.5	1.4	0.2
Dropseed *Sporobolus heterolepsis*	1.4	—	—
Lespedezas *Lespedeza* spp.	1.4	7.5	1.1
Asters *Aster* spp.	1.3	0.5	0.3
Munro grass *Panicum agrostoides*	1.2	0.3	0.8
Common ragweed *Ambrosia artemisiifolia*	1.0	2.9	0.3
Foxtails *Setaria* spp.	0.9	0.2	1.5
Dewberry *Rubus flagellaris*	0.7	0.8	1.8
Horse nettle *Solanum carolinense*	0.6	0.3	1.9
Bluegrasses *Poa* spp.	0.5	1.1	—
Crab grasses *Digitaria* spp.	0.3	0.2	14.7
Switch grass *Panicum virgatum*	0.1	—	8.2
Carpetweed *Mollugo verticillata*	—	0.1	4.6
Mountain mint *Pycnanthemum tenuifolium*	—	1.1	—

[1] Scientific nomenclature according to Fernwald (1950).

Rubiaceae, ranking second in per cent composition, was represented by buttonweed (20.1%). This plant, the most abundant species recorded, occurred in moderate to thick stands but was only rarely recorded in dense growths of broomsedge.

Lanceleaf ragweed (8.7%), goldenrods (4.2%), asters (1.3%), and common ragweed, *Ambrosia artemisiifolia* (1.0%) were the principal components of the family Compositae. These species were scattered throughout the samples, but were less common in the dense stands of broomsedge. At the edges of woods and along waterways goldenrod and aster often formed thick, high growths.

Three-seeded mercury (6.6%) and rushfoil (1.5%) represented the family Euphorbiaceae. The former, not commonly found growing in direct sunlight was abundant in moderate to thick stands of open fields. Rushfoil was noted growing in dense patches which sometimes measured several meters in diameter.

Rushes (6.4%), belonging to the family Juncaceae, were prominent in both upland and lowland fields. Characteristic of low wet areas, these plants were evidence of the poorly drained soils of upland fields.

Polygonaceae, comprised mainly of sheep sorrel, and to a lesser degree by curly dock, *Rumex crispus*, made up 5.1 per cent of the plant composition. Sheep sorrel, an indicator of acid soil, was widely distributed.

Wild beans (2.0%), the major representatives of the family Leguminosae, were recorded in many of the quadrats, but were not numerous. In areas where herbaceous cover was dense, wild bean, partridge pea (1.5%), annual lespedezas (1.4%), and other legumes were scarce.

Further analysis of the flora of the unmanaged areas revealed that, although more perennial species were recorded

than annuals or biennials, the per cent composition was not in this order. Forty-two annuals comprised 61.2 per cent of the plant composition, 45 perennials totaled 34.5 per cent, and 4 biennials yielded 4.3 per cent. The more important annuals were buttonweed, lance-leaf ragweed, three-seeded mercury, three-awned grasses, and cheat. Perennials included a rush, panic grasses, sheep sorrel, perennial rye grass, and broomsedge. The biennials were few and were represented mainly by goldenrods.

The average number of stems recorded per quadrat in the unmanaged areas was 137; the average height of vegetation was 16 inches (Table 3). Estimated per cent bare ground ranged from 0.0 to 70.0 per quadrat and averaged 3.2. Soil samples revealed a median pH of 6.9.

Burned Areas.—A total of 30 plant families totaling 99 species were recorded in 180 quadrats examined in the burned areas. Eight plant families, Gramineae (22.3%), Compositae (21.2%), Rubiaceae (17.5%), Leguminosae (12.8%), Euphorbiaceae (12.6%), Polygonaceae (4.5%), Juncaceae (2.9%), and Labiatae (1.1%) comprised 95.1 per cent of the plant composition (Table 1).

As in the unmanaged areas, Gramineae ranked first in per cent composition. The major species were three-awned grasses (7.7%), panic grass (7.4%), and, to a lesser degree, cheat (2.5%) and broomsedge (1.9%) (Table 2). Three-awned grasses were more abundant on soils supporting a scant herbaceous cover. Broomsedge was observed growing from many of the burned clumps as well as from seeds.

Compositae ranked second in per cent composition. Lanceleaf ragweed (13.9%), a major component of this family (Table 2), occurred in uniform stands. It was the most conspicuous plant wherever burning occurred in open fields. These stands reached a height of 1½ to 2 feet. The typically small, first season's growth of goldenrods (1.8%), the taller asters (0.5%) and common ragweed (2.9%) occurred as either scattered plants or in small patches.

Buttonweed, the only member of the Rubiaceae, comprised 17.5 per cent of the plant composition. This plant was common in the herbaceous substratum and comprised the highest per cent composition of any one species in the burned areas.

Annual lespedezas (7.5%), wild beans (2.3%), and partridge pea (1.4%) were the important plants comprising the Leguminosae. Annual lespedezas were recorded in several areas, one of which was seeded after burning. In the area where seeding occurred, annual lespedeza made up 6.3 per cent of the composition whereas it comprised only 1.2 per cent of the composition in areas not seeded. Wild beans were recorded in practically every sample and were well distributed in the burned areas. Partridge pea occurred in scattered clumps several meters in diameter in many of the burned areas.

The family Euphorbiaceae was comprised mainly of three-seeded mercury (9.8%), and rushfoil (2.5%). These species like buttonweed were most common in areas having medium to light vegetation.

Polygonaceae, made up mainly of sheep sorrel and to a lesser extent curly dock, was well represented in the burned areas. Sheep sorrel was uniformly distributed and made up 4.7 per cent of the composition.

The majority of the flora of the burned areas was composed of annual herbs. Forty-six annual species comprised 71.9 per cent of the composition. The major species were buttonweed, lance-leaf ragweed, three-seeded mercury, three-awned grasses, annual lespedezas, and common ragweed. Forty-nine perennials, comprising 25.7 per cent of the composition and 5 biennials comprising 2.4 per cent, constituted the remaining species. The more prominent perennials were panic grasses, sheep sorrel, rush, and broomsedge. The important biennials were goldenrods and wild carrot, *Daucus carota*.

An average of 176 plants per quadrat was recorded for burned areas (Table 3). The average height of vegetation was 15 inches and bare ground estimates ranged from 0.0 to 85.0 per cent with an average of 23.0 per cent. The median soil pH was 7.0 in lightly burned areas, and 7.4 in severely burned sites.

Fallowed Areas.—A total of 176 quadrats were established in the fallowed areas with 29 families and 74 plant species being recorded. Nine of the families, Gramineae (38.9%), Rubiaceae (35.9%), Polygonaceae (5.4%), Aizoaceae (4.6%), Compositae (3.1%), Leguminosae (3.1%), Solonaceae (1.9%), Rosaceae (1.8%), and Euphorbiaceae (1.3%), comprised 96.7 per cent of the

TABLE 3.—Density, Per cent Bare Ground, Average Height of Vegetation, and Median pH, Recorded on Unmanaged, Burned, and Fallowed Areas for 1954 and 1955, United Electric Coal Companies, Du Quoin, Illinois.

Plant Families	Unmanaged Areas			Burned Areas				Fallowed Areas		
	1954-55 Combined	1954	1955	1954-55 Combined	1954	1955	1954 Sampled in '55	1954-55 Combined	1954	1955
Average Number Plants per Sample.	137	89	226	176	126	235	253	84	24	169
Percent Bare Ground	3.2	3.0	4.2	23.0	24.0	20.8	10.0	46.0	55.0	37.5
Average Height in Inches.....	16	..[1]	16	15	..	15	..	9.6	..	9.6
Median pH.....	6.9	6.9	..	7.2	7.0[2] 7.4[3]	..	..	7.0	7.0	..

[1] Not recorded.
[2] Light Burn.
[3] Heavy Burn.

vegetation (Table 1). These families yielded 13 species with a composition of more than one per cent. Gramineae, ranking first, was well represented by crab grasses, *Digitaria spp.*, (14.7%), two species of panic grass, *Panicum lanuginosum* (8.8%) and *P. virgatum* (8.2%), broomsedge (2.7%), and foxtail grasses (1.5%) (Table 2). Crab, panic, and foxtail grasses, formed a dense carpet of vegetation with little bare ground. Broomsedge was never found in clumps but as first year seedlings.

Buttonweed (36.0%), belonging to the family Rubiaceae, had the highest per cent composition of any plant recorded on the fallow strips. Unlike its occurrence as an understory plant of the herbaceous vegetation in the unmanaged and burned areas, buttonweed was common in the open areas of the newly disturbed ground.

Sheep sorrel, a small plant common in the fallowed areas and the larger, curly dock comprised the family Polygonaceae. These plants together made up 5.1 per cent of the composition. The former, more numerous than curly dock, grew in concentrations.

Carpetweed, *Mollugo verticillata*, was one of the first plants to become established following disturbance of the soil. Of the total plants, it comprised 4.6 per cent of the composition. This plant was common in open areas or where bare ground was persistent, but soon gave way and disappeared as thicker herbaceous cover developed.

Taller herbs occurring in the flora of the fallowed areas were mainly members of the Compositae. Lanceleaf ragweed (1.4%), although not abundant, was well represented in fallowed strips not overgrown with grasses. The same was true of goldenrods (0.5%) and asters (0.3%) which had their greatest development in the second year after fallowing, often growing 3 to 6 feet high.

Two species of wild bean (1.7%), *Strophostyles leiosperma*, and *S. helova*, belonging to the family Leguminosae, were common in fallowed strips having a moderate to light herbaceous cover. Wild beans often grew intertwined with partridge pea (0.2%), ragweeds, and other herbaceous plants.

Dewberry (1.8%), a member of the family Rosaceae, occurred most abundantly where fallowed strips dissected already established clumps. The canes of this plant were prostrate on the ground and formed tangled growths.

In the fallowed areas, 37 annuals made up 65.0 per cent of the plant composition. Thirty-two perennials totaling 34.5 per cent and 5 biennials comprising 0.5 per cent constituted the remaining composition. Important annuals such as buttonweed, crab grasses, and carpetweed comprised over one-half of the plant composition (55.3%). Perennial species having a high per cent composition were panic grasses, sheep sorrel, and broomsedge. Goldenrod was the most abundant biennial recorded.

Bare ground ranged from 0.0 to 100.0 per cent and averaged 46.0 per cent (Table 3). An average of 84 stems was recorded per quadrat. The average height of vegetation was 9.6 inches and median soil pH was 7.0.

Anaylsis of Effects of Burning and Fallowing

In comparing results of the unburned, burned, and fallowed areas, it was evident that about the same major plant species were present in each. Twenty-seven species constituted 90 per cent or more of the plant composition in the three areas. Nineteen major species (those having a composition of 1 per cent or more) made up 89.1 per cent of the composition on unburned sites. Seventeen species totaling 88.7 per cent and 13 species comprising 89.1 per cent made up the majority of the vegetation on the burned and fallowed areas, respectively.

Burning and fallowing resulted in an alteration as to numbers and composition of annual, perennial, and biennial species. Annual species increased from 42 on unburned land to 46 on burned areas. Perennials also increased after burning, showing 45 species in unburned areas and 49 on burned sites. On fallowed land, annual and perennial species showed 37 and 32, respectively. Biennials increased from four on the unburned land to five on burned and fallowed

areas. Annuals comprised 61.2 per cent of the vegetation on unburned areas, 71.9 per cent on burned, and 65.0 per cent on fallowed sections. Perennials represented 34.5 per cent on unburned sites, 25.7 per cent on burned sections and 34.5 per cent in fallowed strips. Biennials yielded 4.3 per cent on unburned, 2.4 on burned, and 0.5 on fallowed areas.

Many plant species increased in abundance as a result of management practices. Species showing major increases in per cent composition due to burning were lanceleaf ragweed, common ragweed, panic grasses, three-seeded mercury, wild beans, three-awned grasses, annual lespedezas, and rushfoil. All of these plants with the exception of the three-awned grasses, are good quail foods. Partridge pea, an important wildlife food, declined in per cent composition in 1954, but an increase and excellent stands were observed in all of the burned areas sampled in 1955. Plants that increased in the fallowed strips were buttonweed, panic grasses, crabgrasses, foxtail grasses, carpet weed, and horse-nettle, *Solanum carolinense*. Dewberry increased from 0.7 per cent in the unburned areas to 1.8 in fallowed strips; subdividing roots and canes probably contributed to this increase.

A few plants decreased after burning and fallowing. Sheep sorrel, rush, asters, goldenrods, cheat, buttonweed, foxtail grasses and panic grass, *Panicum agrostoides*, decreased in composition after burning. Broomsedge, which is of little value to wildlife when it occurs in large, dense stands, decreased from 3.5 per cent on unburned areas to 1.9 per cent on burned sites. Due to fallowing, lanceleaf ragweed, rushes, three-awned grasses, cheat, perennial rye grass, broomsedge, and partridge pea decreased. Broomsedge was virtually eliminated in 1954 but seedlings were recorded on a few fallow strips the following year.

Plant composition 15 to 16 months after burning, as compared to unmanaged and recently burned land, revealed a reduction of buttonweed, sedge, *Carex* sp., rushfoil, broomsedge, and the blue grasses, *Poa* spp. Three-awned grasses and dock showed considerable increases in these areas. Cheat and wild beans also yielded higher compositions in areas unburned for 15 to 16 months.

Because burning on United Electric Land was conducted in early spring, a comparison of data from areas burned in different seasons was not available. Late winter burning according to Stoddard (1941) is most desirable in the Gulf Coast States; however, burning should be conducted after danger of late frost is past. Many wild food plants, particularly partridge pea, are killed by freezing after premature germination in the fire-blackened soil (Lehmann 1937). Burning in spring, after plants have germinated, will also kill many desirable food plants; partridge pea, annual lespedezas, and other annuals will be destroyed. Wild bean, although suppressed by a late spring burn, will usually be stimulated (Lehmann 1937).

As plant composition may vary because of different seasons of burning, plant composition of fallow strips will also be affected by the time of plowing. Because the revegetation of newly disturbed ground is dependent to a large extent on

local weather conditions, it may be advisable to plow strips over a period of several months (Lehmann 1937). Unless the sole purpose of plowed strips is to control burning, strips should not be replowed until completely reverted to the natural vegetation. On our study area plowed strips were necessary in controlling fires but, in order to produce more diversified cover, new strips were plowed adjacent to older ones.

Plant Density.—Marked differences in the unburned, burned, and fallowed areas were evident in the numbers of plants per sample. The density increased from 137 plants in the unburned areas to 176 in areas sampled 3 to 4 months after burning. The greatest number of plants, 253 per quadrat, was recorded in areas sampled 15 to 16 months after burning. This increase in the number of individuals per quadrat was probably a result of the decrease of the dominants as well as more favorable conditions for the growth of dispersed or latent seeds. In the fallowed areas the average number of plants per quadrat was 83. In areas fallowed in 1955, seven times as many plants were recorded than in 1954 (24 plants per quadrat in 1954 and 169 in 1955). This increase was probably due to an increase in precipitation in the spring of 1955.

Bare Ground.—Bare ground was increased approximately 8 times in the burned areas and 14 times in fallowed areas. The ground cover on much of the idle land was composed of dead leaf materials. Broomsedge, when present in concentrated clumps, was responsible for the exclusion of much of the bare ground. On land sampled 3 to 4 months after burning, bare ground averaged 23 per cent. This increase resulted from the destruction of the thick vegetation. After the second growing season, burned areas averaged 10 per cent bare ground, being three times more than that of unmanaged land. Fallowing resulted in the most obvious change in the vegetational cover. In 1954 fallowed strips, bare ground averaged 55.0 per cent while in 1955, bare ground averaged 37.5 per cent. This increase in the vegetational cover in 1955 may have been due to the increase in spring precipitation.

Soil pH.—Although soil conditions were not studied in detail, increases in the median soil pH was noted in the burned areas. The tests for hydronium ion activity indicated a pH of 6.9 for unburned areas, 7.0 for those lightly burned, and 7.4 for those heavily burned. The relatively high readings are not in accordance with the acid conditions of the soil as determined for application of agricultural lime. However, the increase from unburned to light, to severe burn may show a trend in alteration of soil pH due to burning. Partridge pea and other legumes grow best on basic soils and if burning does alter pH, the result would definitely favor the growth of these legumes.

Burning and Fallowing as Management Tools

The unmanaged land on this property was once considered to support some of the best quail populations in southern Illinois. This was approximately 4 to 5 years after the land had been removed from culti-

vation. As the land remained idle, annual food plants and general cover conditions suitable to quail were replaced by thick, non-food producing vegetation. Eventually, with the invasion of woody herbs and trees, climax vegetation could be expected to become established. As pointed out by Lehmann (1937) a climax, whether grass or forest, is not usually favorable to quail. Food plants and cover necessary for good quail populations are those associated with the early successional stages.

To be a useful quail management tool, burning must be done often enough to sustain the most productive habitat. In Michigan, burning every 1 or 2 years produced herbaceous vegetation of bluegrass, aster and goldenrod which would last indefinitely as long as controlled burning was practiced (Beckwith 1954). Infrequent burning only retarded the natural succession and more woody plants became established. From our study, initial observations indicated that more diverisfied habitat was established when one-third of the land was burned each year. As a result of this plan, three specific habitats were produced, each of which meet certain needs of quail. A few months after burning, a limited amount of plant cover was established to provide some nesting cover; one successful nest was recorded from one such area. More importantly, recent burns made more seeds and insects accessible, offered dusting areas, gave a more desirable roosting habitat, and, in general, made it possible for quail to get their feet on the ground. The latter seemed to be a prime requisite in quail management programs in southeastern United States (Scott and Klimstra 1954). Evidences of the above utilization were repeatedly observed during field studies of the quail populations. In fact, greatest activity in late summer was observed in the annual food patches where cover was even less dense and more bare ground was exposed than on burned areas. In the second year after burning, the land would fulfill somewhat the same requirements. However, plant composition, density of vegetation, and per cent of bare ground would be less desirable. In areas unburned for 2 years, vegetation would be similar to that in the unmanaged fields, although broomsedge would probably not be well established. These conditions are important as sources of nesting and escape cover, and during periods of adverse climatic conditions. Desirable nesting sites for quail offer accumulated vegetation from the previous year's growth. The alternate burning suggested would offer great diversity of plants throughout a given area resulting in an environment more acceptable to wildlife.

More food and cover was provided in the open fields by protecting small trees and thickets from fire. This precaution increased the diversification of the habitat and established nesting, roosting, and escape cover, near a source of annual foods. Unburned strips along the edges of fields were also useful as a protective transitional zone between the open ground cover of the wooded fence rows and the light cover of the burned fields.

As a result of burning, mechanical stimulus or chemical alterations of the soil probably influenced the re-

sulting vegetation. Hard seed coats of partridge pea and rushfoil were possibly scarified by heat during burning resulting in greater germination. Reduction of competition, and generally more favorable growing conditions were believed responsible for the increased production of certain plants. Burning may also have made available plant foods.

Fallowed strips were not particularly important for the amount of food and cover provided; however, because bobwhite quail prefer traveling on the ground, these strips were important in linking parts of their habitat and in making more feeding areas accessible. The fallowed strips served as travel lanes, and feeding, roosting, and nesting could be carried on short distances from their edges. According to Stoddard (1941: 21) ". . . the bobwhite in nesting shows a marked partiality for the vicinity of roads, paths, edges of fields, and similar open situations." In his studies, 74 per cent of all nests were within 50 feet or less of such openings. Therefore, well placed strips dividing otherwise featureless vegetation would be beneficial in producing more edge, resulting in greater diversification of vegetation. Quail prefer a light, dry soil for dusting sites, and fallowed areas would be extremely attractive.

The history of uncontrolled burning is indicative of its disastrous effects on wildlife. Controlled burning, during seasons when desirable plants are destroyed, is likewise harmful. Even though vegetational conditions were improved for quail, burning did result in the destruction of cover favorable to the cottontail rabbit. Burning was conducted at a time when rabbits were bearing young, and it is likely that some nests were destroyed. "Fire is rightly comparable to a two-edged sword. While it may be used to good advantage at times to obtain definite desired results, its abuse, or careless uncontrolled use, may be productive of great harm" (Stoddard 1941; 414).

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IDENTIFICATION OF HORSERADISH TYPES

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ABSTRACT.—Thirty horseradish cultivars were grouped into three types based on differences in morphological characteristics and disease reactions. Type I, known as Bohemian, has smooth lanceolate to oblanceolate radical leaves that taper acutely at the base. The plants are resistant to Turnip mosaic 1 and whiterust diseases. Type II has smooth to slightly crinkled ovate to obovate radical leaves that are rounded at the base. The plants are very susceptible to Turnip mosaic 1, expressed as a ringspot symptom, and are intermediate in resistance to white-rust. Type III, known as common, has crinkled, cordate radical leaves and is susceptible to Turnip mosaic 1, expressed as a mosaic, and to white-rust.

Horseradish, *Armoracia rusticana* Gaertn., Mey. & Scherb., is one of the oldest and best known condiments, valued for the fleshy tap-roots which have an extremely pungent flavor. Approximately 15,000,000 pounds of horseradish are processed annually for consumption in the United States, according to the National Association of Horseradish Packers. Over 1,500 acres of horseradish, or approximately 60 per cent, are grown on deep, fertile, loessial soils in the Mississippi River Valley around East St. Louis, Illinois.

Horseradish cultivars are generally divided by commercial growers and handlers into two types, "common" and "Bohemian". The common type has broad crinkled leaves and produces a root of high quality for processing. The Bohemian type has narrow smooth leaves, is more resistant to certain diseases, and generally produces a root of lower quality than the common type.

The horseradish plant is highly sterile and is propagated asexually by roots (Brzezinski, 1909 and Weber, 1949). Lack of natural seed production has reduced the possibility of developing new cultivars. Viable seeds, however, have been produced under certain controlled conditions. Brzezinski (1909) was probably the first to grow horseradish from seed. Later Weber (1949) and Moravec (1963) reported success in obtaining viable seeds. Seedlings have also been obtained during the past five years at the Illinois Agricultural Experiment Station. In evaluating seedlings and cultivars, it was evident that horseradish cultivars should be grouped into three types rather than the two types, which are commonly recognized by growers and processors.

MATERIALS AND METHODS

Data on morphological plant characteristics and disease symptons were taken on 15 cultivars grown near East St. Louis in 1962 and 30 cultivars grown at Urbana in 1963, with 15 cultivars common to both locations.

In the East St. Louis planting, the side and crown roots were removed to promote development of a

TABLE 1. Characteristics of Horseradish Cultivars

Illinois Accession Number	Name or Source[1]	Leaf Blade Length/Width Ratio		Leaf Texture[2]	Turnip mosaic 1		White-rust[3]
		Urbana	E. St. Louis		Rating[3]	Symptom	
TYPE I (Leaf base angle less than 60°)							
103a	Russia	4.6	4.7	S	1	Black veins	1
93a	Illinois A.E.S.	4.0		S	0	None	1
104a	Russia	3.9	4.1	S	1	Black veins	1
161a	Wis. C-31	3.7		S	0	None	1
156a	Wis. E-4	3.5		S	1	Black veins	0
162a	Wis. Z-1	3.2	3.2	S	1	Black veins	1
167a	Bohemian	3.1		S	0	None	0
204a	Big Top Western	3.1	3.6	S	0	None	1
119a	Sass	3.0	3.4	S	0	None	1
142a	Wis. P-4	3.0	3.2	S	0	None	1
TYPE II (Leaf base angle 60°-90°)							
135a	Wis. Y-7	3.1		S	4	Rings	1
28a	Illinois A.E.S.	3.1		S	5	Rings	1
209a	Swiss P	3.0	3.1	S	5	Rings	0
113a	Russia	2.9	2.9	S	4	Rings	0
208a	Swiss F	2.8	3.2	S	5	Rings	0
152a	Wis. X-1	2.8	2.7	SC	4	Rings	0
8a	Illinois A.E.S.	2.8		SC	5	Rings	0
136a	Wis. N-2	2.6		S	5	Rings	0
163a	Wis. P-15	2.4	2.7	S	3	Rings	3
131a	Wis. L-3	2.3		C	3	Rings	0

TYPE III (Leaf base angle greater than 90°)

286a	Illinois A.E.S.	2.3		C	5	Mottling	4
157a	Wis. Y-8	2.3		C	0	None	4
140a	Wis. N-9	2.2		C	0	None	0
213a	Common S	2.1		C	4	Mottling	5
138a	Wis. N-4	2.0		C	1	Black veins	0
205a	Old Jersey	2.0	2.2	C	1	Mottling	4
212a	Japan	2.0	2.3	C	5	Mottling	4
206a	Common B	2.0	2.3	C	5	Mottling	5
165a	Common J	1.9		C	4	Mottling	4
211a	Japan	1.9	2.5	C	5	Mottling	3

[1] Wisconsin (Wis.) cultivars originated from Weber's (1949) studies.
[2] Texture: S=smooth, SC=slightly crinkled, C=crinkled.
[3] Rating: 0=highly resistant, 5=highly susceptible.

large primary root, a common commercial practice. In the Urbana planting, no roots were removed. All plants were grown from root cuttings approximately 0.5 inch in diameter and 10 to 14 inches in length.

Leaf measurements were taken during September, as leaf characteristics are more pronounced and consistent at this time. For each cultivar, several mature and radical leaves were measured for length and width of the leaf blade, length of petiole, and leaf base angle. The leaf base angle is an angle subtended by an arc drawn from the midrib of the leaf blade to the basal margin of the leaf blade. Observations were made for shape, margin, and texture of the leaves. Petioles were recorded as either solid or hollow at the base of the leaf blade. Several cultivars were flowered to observe the inflorescence.

Each cultivar was rated for field susceptibility to the following diseases: White-rust, *Albugo candida* (Pers. ex Chev.) Kuntze, bacterial leaf spot, *Xanthomonas campestris* var. *armoraciae* (McCul) Starr & Burkholder, Cercospora leaf spot, *Cercospora armoraciae* Sacc., Ramularia leaf spot, *Ramularia armoraciae* Fckl., and Turnip mosaic 1, *Marmor brassicae*.

Results and Discussion

The 30 cultivars studied were grouped into three types based on certain morphological characteristics and disease reactions of mature radical leaves. Texture, basal angle and length/width ratio of the leaf blade, together with disease susceptibility were the distinguishing characters. Others characters including differences in petiole, inflorescence, and leaf shape helped to distinguish the types. Consideration was given to combination of these characters since variations occurred within types.

Leaves. The basal angle of mature leaf blades, although difficult to measure precisely, separates Type III from Types I and II (Table 1). This angle is obtuse for Type III but acute for Types I and II. The leaf base angle is tapered for Type I (less than 60°) and rounded for Type II (between 60 and 90°) (Table I and Fig. 1). The length/width (L/W) ratio of the leaf blade is greatest for Type I, intermediate for Type II, and least for Type III (Table 1).

Leaf texture of Type III is distinctly crinkled, and the leaf margins are generally wavy (Fig. 1). Type I has smooth leaves and Type II has smooth to slightly crinkled leaves.

Pinntaifid leaves appeared in August and September. By October, some cultivars of Type III produced only pinnatifid leaves. Cultivars of Types I and II produced fewer pin-

Figure 1. Characteristic mature radical leaf of Type III (left), Type II (center) and Type I (right) horseradish plant.

natifid leaves than Type III, although individual exceptions occurred. This characteristic has been shown by Pound (1949) to occur in Type III at temperatures lower than 20° C. Other workers have suggested that the presence of such leaves is due to a photoperiodic response (Endo and Linn, 1960) or virus infection (Kadow and Anderson, 1940 and Novak and Vlk, 1950). However, Pound (1949) demonstrated that changing temperatures affected the leaf shape, even though 100 per cent of Type III plants were infected with mosaic virus.

In September, mature petioles of Types I and II were usually solid and petioles of Type III were usually hollow at the base of the leaf blade. In November, petioles of Types I and II tended to become hollow as the leaves reached senescence. The length of the petiole within cultivars varied with location. Observations on other leaf characteristics such as shape and margin are shown in Table 2.

Inflorescence. Horseradish flowers are arranged in paniculate racemes (Table 2). The racemes of Types I and II are uniformly elongated to form rounded panicles (Fig. 2). The lower racemes of Type III tend to elongate more than the terminal racemes, to give the inflorescence the appearance of a corymb (Fig. 2). The inflorescence of Type III frequently failed to develop and flowers aborted before opening. The inflorescence of Type III was generally smaller in size than either Type I or II. The cauline leaves, usually sessile, tended to be similar in form to the mature radical leaves.

Diseases. Although Type II is similar to Type I in some morphological respects, suceptibility of Type II to

FIGURE 2. Characteristic inflorescence of Type I (left) and Type III (right) horseradish plant.

TABLE 2. Distinguishing Characteristics of Horseradish Types

Character	Type I	Type II	Type III
LEAVES			
Shape	Lanceolate to Oblanceolate	Ovate to Obovate	Cordate
Length/width ratio	Greater than 3.0	2.4 to 3.0	Less than 2.4
Base	Tapering	Rounded to Abrupt	Cordate
Base angle	Acute (less than 60°)	Acute (60 to 90°)	Obtuse (greater than 90°)
Surface Texture	Smooth	Smooth to slightly crinkled	Crinkled
Margin	Serrate to Crenate	Crenate	Crenate
Petiole	Solid	Usually solid	Usually hollow
Pinnatifid leaves	Few late in season	Few late in season	Many late in season although variable
INFLORESCENCE			
Form	Elongated paniculate raceme	Elongated paniculate raceme	Paniculate raceme, corymbose shape
Cauline leaves	Linear to lanceolate	Lanceolate	Lanceolate to ovate, lower leaves usually pinnatifid
DISEASES			
Turnip mosaic 1	No visible symptoms	Ringspot	Mottling and chlorosis
White-rust	Resistant	Intermediate	Susceptible

Turnip mosaic 1 (*Marmor brassicae*) separated it from Type I. All plants of Types II and III surveyed have been visibly infected with Turnip mosaic 1, expressed as a ringspot in Type II and mosaic mottling in Type III (Table 1 and Fig. 3). Also, characteristic of Turnip mosaic 1 was the formation of somewhat sunken black streaks in the petioles and midribs, that reached the crown as the season progressed. Blackening of the smaller leaf veins occurred in some cultivars.

White-rust (*Albugo candida* (Pers. ex Chev.) Kuntze) is one of the most prevalent and destructive diseases of horseradish (Endo and Linn, 1960; and Kadow and Anderson, 1940). Cultivars of Type I possess high resistance to white-rust while cultivars of Type III are very susceptible (Table 1). Cultivars of Type II differed considerably in resistance and susceptibility and are considered intermediate between Types I and III.

Bacterial leaf spot (*Xanthomonas campestris* var. *armoraciae* (McCul) Starr & Burkholder) sometimes is quite severe. Type III proved to be very susceptible and the older leaves were completely covered with necrotic lesions following cool, rainy weather. Cultivars of Types I and II varied from highly resistant to moderately susceptible to bacterial leaf spot. This disease is questionable as a diagnostic character to identify types of horseradish.

Cercospora (*Cercospora armoraciae* Saccardo) and Ramularia (*Ramularia armoraciae* Fuckel) leaf spot diseases, generally common wherever horseradish is grown, were not prevalent or consistent enough in these plots to determine relative susceptibility and resistance of cultivars within the three types.

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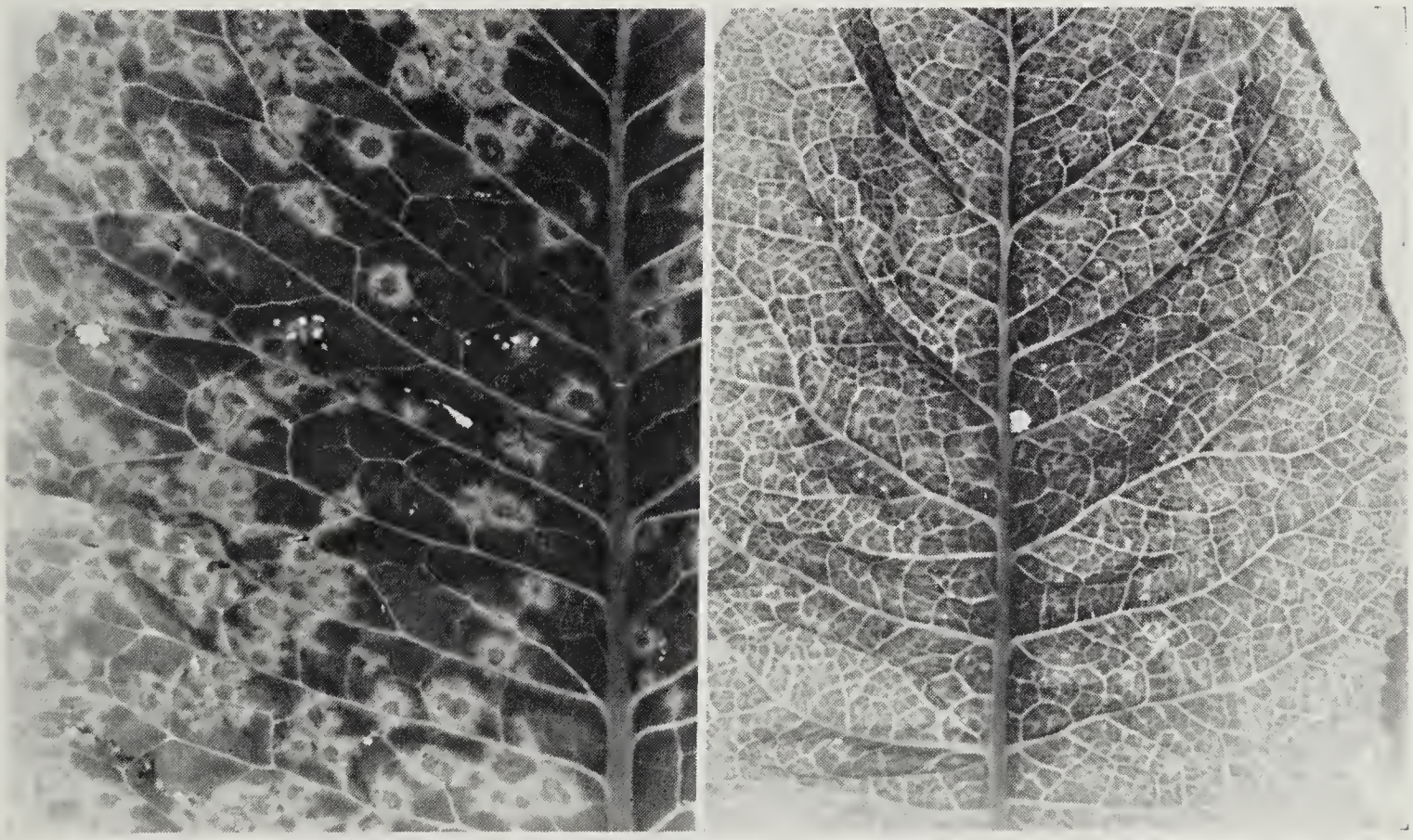

Figure 3. Characteristic virus symptoms: Ringspot on horseradish leaf of Type II (left) and mosaic on Type III (right).

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THE PERFORMANCE OF A MARYLAND SOURCE OF LOBLOLLY PINE IN EAST-CENTRAL ILLINOIS

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ABSTRACT.—A 16-year-old plantation of loblolly pine (*Pinus taeda* L.), established in east-central Illinois from a Maryland seed source, is 325 miles north of its natural range in Tennessee. This is the northernmost plantation of this species in Illinois, which can be considered successful from the standpoint of survival, growth, and hardiness. The apparent success of loblolly pine at this northerly location suggests a greater use of it for forest planting in southern Illinois.

Loblolly pine (*Pinus taeda* L.) is an important commercial timber species in the southern United States. Because of its fast growth, its adaptability to a wide variety of soils, and its excellent qualities as a timber tree, it has been used extensively for reforestation outside of its natural range. One of the earliest plantings on record of loblolly pine in Illinois was made in 1932 by the University of Illinois at Elizabethtown, Hardin County. In Illinois it has been planted mostly south of United States Highway 40 (approximately 39 degrees north latitude); however, even here its use has been limited because of its questionable hardiness.

Minckler (1950) found that after one growing season in southern Illinois, trees from South Carolina and Mississippi seed sources had greater mean heights than did sources from Arkansas, North Carolina, Maryland, and Virginia. However, the trees from Mississippi, North Carolina, and South Carolina seed sources were severely frost damaged during the second winter after planting (Minckler, 1952). He concluded that the trees from seed collected in Maryland and Virginia were definitely superior for planting in upland, old fields of southern Illinois. At age 10 trees from a Maryland seed source had the greatest mean diameter, mean height, and basal area per acre (Woerheide, 1959).

This study reports on the survival and growth of a 16-year-old plantation of loblolly pine at the Robert Allerton Park in east-central Illinois (Lat. 40° 05′ N., Long. 88° 40′ W.).

DESCRIPTION OF PLANTATION

The Allerton plantation in Piatt County was established April 1948 with one-year-old seedlings from a Maryland seed source. Approximately 1,200 trees were planted on one acre. This is the most northerly plantation of loblolly pine in Illinois with sufficient survival to exhibit normal stocking. The nearest native loblolly pine is 325 miles south in Tennessee. The soil is classified by the Illinois Soil Survey as Sunbury silt loam (No. 234). This is a grayish-brown silt loam which is a transition between Gray-Brown Podzolic forest soils and Brunizem soils. It has moderate surface drainage.

Climatic Factors

The mid-continental location and latitude of Illinois result in hot summers and cool to cold winters, often with rapidly fluctuating temperatures. Piatt County has approximately 175 frost-free days and 37 inches of annual rainfall with good distribution during the growing season (Page, 1949). January is usually the coldest month of the year. Average monthly temperatures fall below 32° F. for December, January, and February. Minimum temperatures recorded by the Weather Bureau (1948-1963) for Urbana, which lies 25 miles to the east, are listed in Table 1. According to these data, the plantation withstood a low temperature of approximately —15° F., during the winter following its third growing season, without serious injury.

The Allerton plantation was subjected to a severe ice storm during the period of January 19 through 21, 1959, when it was 11 years old. Ice accumulated on the twigs and branches to a thickness of one-half to one inch. State Climatologist Lother A. Joos labeled this storm as the worst recorded for east-central Illinois during the preceding 50 years. The tops of 30 per cent of the trees in the Allerton plantation were broken by the weight of the accumulated ice. No appreciable ice damage occurred in the adjacent plantations of jack, red, and white pines. The greater susceptibility of loblolly pine to cold weather and glaze damage, compared to other conifers in southern Illinois plantations, was described by Boggess and McMillan (1954).

Table 1.—Minimum Temperatures Recorded at Urbana, Illinois, During the Years 1948 Through 1963 by the Weather Bureau.

Dec. 22, 1948	4° F.
Jan. 30, 1949	—3° F.
Nov. 25, 1950	—5° F.
Feb. 2, 1951	—18° F.
Jan. 29, 1952	2° F.
Dec. 17, 1953	1° F.
Jan. 17, 1954	—1° F.
Feb. 11, 1955	—9° F.
Jan. 23, 1956	1° F.
Jan. 14, 1957	—6° F.
Dec. 9, 1958	—6° F.
Jan. 5, 1959	—9° F.
Dec. 23, 1960	—11° F.
Jan. 28, 1961	—5° F.
Jan. 10, 1962	—10° F.
Jan. 23, 1963	—14° F.

Growth

The early survival and growth of loblolly pine at Allerton Park are remarkable, considering its northerly location. Survival and height data are given in Table 2. The excellent growth of this species of pine is best shown by comparing it with the growth of five other species on comparable sites in the same field. Loblolly pine, at age 16, had the greatest diameter and height growth as shown in Table 3. A stand and stock table is presented for the plantation in Table 4. The mean height

Table 2.—Average Height and Percent Survival of Loblolly Pine at the Robert Allerton Park.

Plantation age, years	Average height, ft.	Survival, percent
1	0.9	98
2	2.3	96
3	4.0	92
4	5.7	88
5	8.3	87
10	24.9	86
16	37.3	73

of the dominant and codominant trees of 39 feet, at age 16, corresponds to a site index of 50 at age 25, according to site index curves developed by Gilmore and Metcalf (1961) for plantation loblolly pine in southern Illinois.

Discussion

There are 750,000 acres in the southernmost 16 Illinois counties in need of reforestation (Spaeth, 1948). Most of the area would be highly productive if planted to pine. The growth performance of the rather frequently planted shortleaf pine (*Pinus echinata*) in southern Illinois has been generally poor and below that of loblolly pine. Boggess and Gilmore (1963) have confirmed the superior growth of loblolly pine over that of shortleaf pine in southern Illinois.

Conclusions

The loblolly pine plantation at the Robert Allerton Park in east-central Illinois is the northernmost plantation of this species in Illinois which can be considered successful from the standpoint of survival, growth and hardiness. An interest has been shown in the plantation for breeding purposes and as a possible seed source for the production of hardy planting stock. Efforts to establish plantations

Table 3.—Diameter and Height of Loblolly and Other Species of Pine at the Robert Allerton Park, Age 16 Years.

Species	Average diameter breast high, in.	Average height, ft.
Red pine (*P. resinosa* Ait.)	4.7	23
Jack pine (*P. banksiana* Lamb.)	3.7	24
Shortleaf pine (*P. echinata* Mill.)	4.8	28
E. white pine (*P. strobus* L.)	5.0	29
Virginia pine (*P. virginiana* Mill.)	5.1	31
Loblolly pine (*P. taeda* L.)	5.4	37

Table 4.—A Stand Table for Loblolly Pine, Robert Allerton Park, Plantation Age 16 Years.

Diameter, breast high, in.	Trees per acre, no.	Basal area per acre, sq. ft.	Curved height, ft.	Total peeled volume per acre ($.0024D^2H$), cu. ft.
3	7	0.4	29	
4	141	13.7	34	185
5	355	49.6	37	791
6	289	57.1	39	978
7	59	15.1	39	272
8	7	2.2	40	43
	858	138.1	.....	2,273

of loblolly pine from Arkansas seed sources at Urbana during the years 1952, 1953, and 1955 and at Allerton Park in 1962 failed because of winter injury. The apparent success of the 16-year-old plantation of loblolly pine, established at Allerton Park from a Maryland seed source, does not justify its use for forest planting in central Illinois. Nevertheless, the excellent growth and hardiness qualities exhibited by this plantation would certainly indicate a greater use of this species for forest planting in southern Illinois.

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CHANGES IN DISTRIBUTION AND ABUNDANCE OF PHEASANTS IN ILLINOIS: 1958 VERSUS 1963

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ABSTRACT.—The relative abundance of pheasants in April, as reported by rural mail carriers in the 74 northernmost counties of Illinois, increased from 7.8 birds per 100 miles of driving in 1958 to 9.9 birds per 100 miles in 1963, or 27 per cent. In both censuses, pheasants were most abundant in east-central Illinois. Gains in pheasant abundance between 1958 and 1963 occurred in east-central Illinois and immediately southwestward; significant decreases in pheasant abundance occurred in the northern and northwestern portions of the state.

A prerequisite to intelligent management of the ring-necked pheasant (*Phasianus colchicus*) is a knowledge of changes in patterns of distribution and abundance of its populations. This exotic game bird, introduced into Illinois in the 1890's (Robertson 1958, p. 3), has succeeded in establishing self-maintaining populations in approximately the northeastern third of the state. Its center of abundance, since the mid-1930's, has been in the intensively cultivated cash-grain areas of east-central Illinois (Greeley, Labisky, and Mann 1962, pp. 13-16). The pheasant was first hunted legally in Illinois in 1915 (Robertson 1958, p. 6), and has since become an important game species. The fall harvest of cocks by hunters averaged 835,000 annually from 1956 through 1963 (William L. Preno, Illinois Department of Conservation, personal communication, August 30, 1964).

This paper discusses the distribution and abundance of pheasants in Illinois as reported by rural mail carriers during a census in April, 1958, and in April, 1963. The results of the 1958 census of pheasants were presented, in part, in an earlier publication (Greeley, et al. 1962).

METHODS

The pheasant census data reported in this paper were collected by rural mail carriers who counted pheasants that they observed along their routes during the 5-day periods of April 21-25, 1958, and April 22-26, 1963. A detailed description and evaluation of the rural mail carrier method of censusing pheasants in Illinois was published by Greeley, et al. (1962, pp. 3-5). The censuses were conducted in April because Greeley, et al. (1962, p. 5) reported: "The conditions for observing pheasants are probably more nearly constant from year to year in April than in any other month. April, therefore, may be the best time to use rural mail carrier censuses for obtaining annual indices of pheasant abundance."

The census of pheasants was conducted in 74 of Illinois' 102 counties in both 1958 and 1963. Greeley, et al. (1962, p. 14) had previously classified a contiguous block of 28 counties in southern Illinois as non-

pheasant range because no pheasants were observed in these counties during a February, 1957, census by rural mail carriers.

In 1958 and 1963, questionnaires (postcards), with letters of instruction, were mailed to postmasters of all post offices having rural routes in the 74 counties to be censused. Each postmaster was requested to distribute the postcard questionnaires, and the instructions, to the rural mail carriers operating from his post office. The mail carriers were asked to report the counties and political townships in which their routes were located, the length of their routes in miles, and the numbers of pheasants (cocks and hens) observed along the routes on each of the 5 consecutive days specified in the instructions.

If the route of a mail carrier extended into two or more townships, the number of pheasants observed was divided equally among all the townships reported on his questionnaire. The number of miles driven and the number of pheasants seen during the 5-day census period were used to calculate the number of pheasants observed per 100 miles of driving in each township and each county.

Findings

The voluntary participation by rural mail carriers in the April, 1963, census of pheasants was considerably greater than in any of six pheasant censuses conducted in Illinois during 1957 and 1958 (Greeley, et al. 1962, p. 5). Of the 1,320 questionnaires distributed to rural mail carriers via their postmasters in April, 1963, 1,202 (91 per cent) were returned; 1,150 (87 per cent) of the 1,320 contained usable data.

The relative abundance of pheasants in the 74 northernmost counties of Illinois increased from 7.8 pheasants per 100 miles of driving in April, 1958, to 9.9 pheasants per 100 miles in April, 1963, an overall increase of 27 per cent (Table 1); however, proportionate increases did not occur rangewide (Table 2).

Pheasants increased in abundance between 1958 and 1963 in the counties of east-central Illinois, which have harbored the state's major center of pheasant abundance for the past 30 years, and in the counties immediately south-southwestward (Fig. 1 and 2). In April, 1958, the 10 counties of the state in which pheasants were most abundant were, in descending order of abundance (Table 2): Livingston, Ford, Iroquois, McLean, Champaign, Vermilion, Woodford, Kankakee, Marshall, and Grundy. Correspondingly, in April, 1963, the 10 top-ranked counties included Livingston, Ford, Iroquois, McLean, Champaign, Piatt, Woodford, Kankakee, Putnam, and Grundy; all of these counties showed increases in abundance between 1958 and 1963 (Table 2). The east-central counties of Livingston, Ford, Iroquois, McLean, and Champaign, in that order, occupied positions one to five with respect to relative abundance of pheasants by counties in both 1958 and 1963. These five counties accounted for 56 per cent of all pheasants reported in April, 1958, and 68 per cent of all pheasants reported in April, 1963. In both censuses, pheasants were most abundant in Livingston County, in

TABLE 1.—Comparison of Miles Driven and Adult Pheasants Reported by Rural Mail Carriers From 74 Counties of Illinois in April, 1958 and 1963.

Category	April, 1958	April, 1963
Miles Driven	250,917	318,605
Cocks Observed	10,289	17,225
Hens Observed	9,277	14,466
Total Pheasants Observed	19,566	31,691
Sex Ratio: Hens Per Cock	0.9	0.8
Cocks Per 100 Miles	4.1	5.4
Hens Per 100 Miles	3.7	4.5
Total Pheasants Per 100 Miles	7.8	9.9

TABLE 2.—Comparison of Statistics of Pheasant Abundance, by County, as Reported by Rural Mail Carriers of Illinois during April, 1958 and 1963. Seventy-four of Illinois' 102 Counties were Censused; 28 Counties of Southern Illinois had been Previously Classified as Non-pheasant Range.

	County Rank		Total Pheasants Reported		Pheasants per 100 Miles		
County	1958	1963	April 1958	April 1963	April 1958	April 1963	Percentage Difference: 1958 to 1963[1]
Livingston	1	1	3,634	8,181	56.4	99.1	+ 76*
Ford	2	2	1,569	2,696	50.7	75.8	+ 50*
Iroquois	3	3	1,991	3,674	28.9	43.4	+ 50*
McLean	4	4	2,071	3,867	27.7	43.1	+ 56*
Champaign	5	5	1,641	3,018	25.7	35.6	+ 39*
Piatt	12	6	305	986	11.8	34.6	+ 193*
Woodford	7	7	717	852	15.6	21.8	+ 40*
Kankakee	8	8	706	973	15.3	19.7	+ 29*
Putnam	13	9	81	131	10.8	19.1	+ 77*
Grundy	10	10	323	429	12.5	17.7	+ 42*
De Witt	19	11	190	547	6.5	16.1	+ 148*
Marshall	9	12	328	395	14.6	15.0	+ 3 ns
Douglas	15	13	204	487	8.7	14.3	+ 64*
La Salle	11	14	873	1,233	12.4	13.8	+ 11*
Moultrie	37	15	27	301	1.4	11.3	+ 707*
Vermilion	6	16	966	728	17.3	11.1	— 36*
Logan	16	17	305	344	8.3	9.7	+ 17*
Tazewell	21	18	284	343	6.1	8.5	+ 39*
Macon	42	19	27	326	0.7	6.6	+ 843*
Mason	30	20	66	148	2.7	5.4	+ 100*
De Kalb	14	21	367	261	10.4	5.2	— 50*
Kendall	17	22	134	131	7.4	4.8	— 35*
Du Page	25	23	93	117	4.9	4.3	— 12 ns
Edgar	24	24	190	214	5.0	4.2	— 16*
McHenry	18	25	280	200	7.0	3.9	— 44*
Lee	20	26	243	147	6.2	3.1	— 50*
Will	26	27	208	179	4.6	3.0	— 35*
Kane	28	28	116	98	3.6	2.7	— 25*

TABLE 2.—Continued

County	County Rank		Total Pheasants Reported		Pheasants per 100 Miles		Percentage Difference: 1958 to 1963[1]
	1958	1963	April 1958	April 1963	April 1958	April 1963	
Coles	31	29	60	86	2.0	2.3	+ 15 ns
Cook	29	30	92	61	2.8	1.6	— 43*
Lake	32	31	60	66	2.0	1.2	— 40*
Christian	52	32	9	67	0.2	1.2	+ 500*
Carroll	33	33	40	39	1.9	1.1	— 42*
Menard	43	34	8	18	0.6	1.0	+ 67 nv
Boone	23	35	112	21	5.1	1.0	— 80*
Cass	53	36	4	18	0.2	0.8	+ 300 nv
Winnebago	36	37	46	22	1.5	0.6	— 60*
Sangamon	47	38	17	43	0.3	0.6	+ 100*
Shelby	54	39	11	35	0.2	0.5	+ 150*
Stark	27	40	63	9	4.2	0.5	— 88*
Ogle	35	41	76	26	1.5	0.5	— 67 ns
Bureau	38	42	66	28	1.3	0.5	— 62*
Mercer	55	43	2	15	0.1	0.5	+ 400 nv
Stephenson	22	44	201	18	5.4	0.3	— 94*
Jo Daviess	39	45	37	15	1.2	0.3	— 75*
Henry	34	46	88	19	1.8	0.3	— 83*
Whiteside	48	47	15	13	0.3	0.3	0 ns
Morgan	57	48	2	5	0.1	0.2	+ 100 nv
Peoria	46	49	16	6	0.4	0.1	— 75*
Jasper	40	50	33	4	1.0	0.1	— 90*
Clark	56	51	3	5	0.1	0.1	0 nv
Rock Island	59	52	3	2	0.1	0.1	0 nv
Greene	58	53	2	3	0.1	0.1	0 nv
Montgomery	60	54	3	4	0.1	0.1	0 nv
Warren	49	55	9	3	0.3	0.1	— 67*
Effingham	41	56	4	2	0.3	0.1	— 67*
Knox	62	57	2	3	0.0+	0.1	nv
Cumberland	50	58	6	2	0.3	0.1	— 67 nv
Macoupin[2]	.....	59	0	1	0.0	0.0+	nv
Jersey	.....	60	0	1	0.0	0.0+	nv
Richland-Madison[3]	.....	61	0	1	0.0	0.0+	.....
Crawford	.....	.....	0	0	0.0	0.0	0
Clay	51	.....	5	0	0.3	0.0	— 100 nv
Fayette	61	.....	4	0	0.1	0.0	— 100 nv
Bond	.....	.....	0	0	0.0	0.0	0
Pike	63	.....	1	0	0.0+	0.0	0 nv
Scott	.....	.....	0	0	0.0	0.0	0
Brown	.....	.....	0	0	0.0	0.0	0
Adams	.....	.....	0	0	0.0	0.0	0
Hancock	.....	.....	0	0	0.0	0.0	0
Schuyler	.....	.....	0	0	0.0	0.0	0
McDonough	44	.....	19	0	0.6	0.0	— 100*
Henderson	45	.....	10	0	0.5	0.0	— 100 nv
Fulton	64	.....	1	0	0.0+	0.0	0 nv

[1] The difference in the abundance of pheasants per 100 miles of driving between 1958 and 1963 in each county was tested for statistical significance by conventional Chi-square analysis. * indicates significance at the 0.05 level; ns indicates no significance at the 0.05 level; and nv indicates that the test was not valid because minimum expected values were 10 or less.

[2] No rank assigned to counties from which pheasants were absent.

[3] Madison County substituted for Richland County in 1963 census.

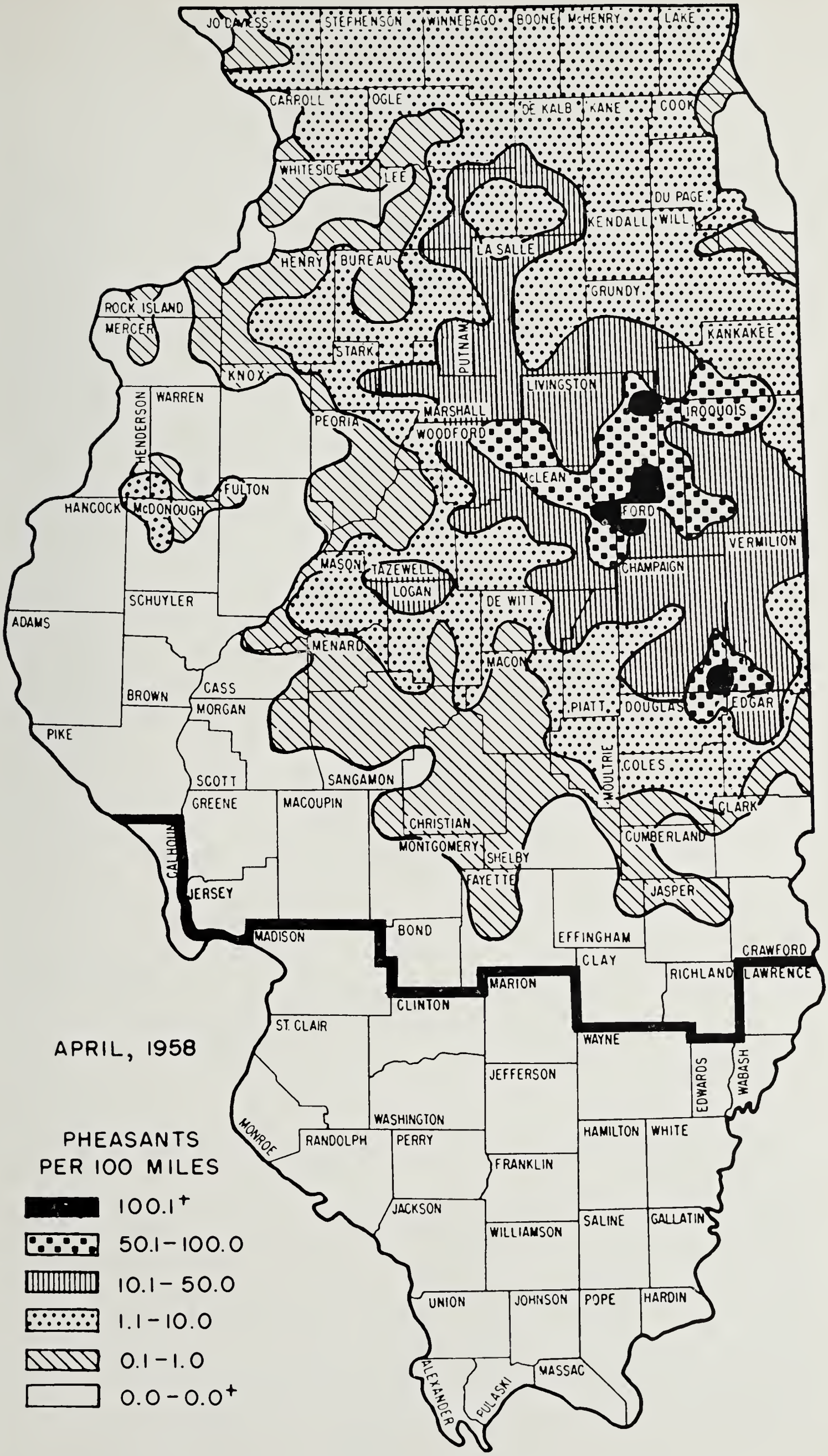

FIGURE 1.—Distribution and abundance of pheasants in Illinois as mapped from data (township) obtained through a rural mail carrier census, April, 1958. This map modified from Greeley, et al. (1962, p. 9). Counties below the heavy line were not censused.

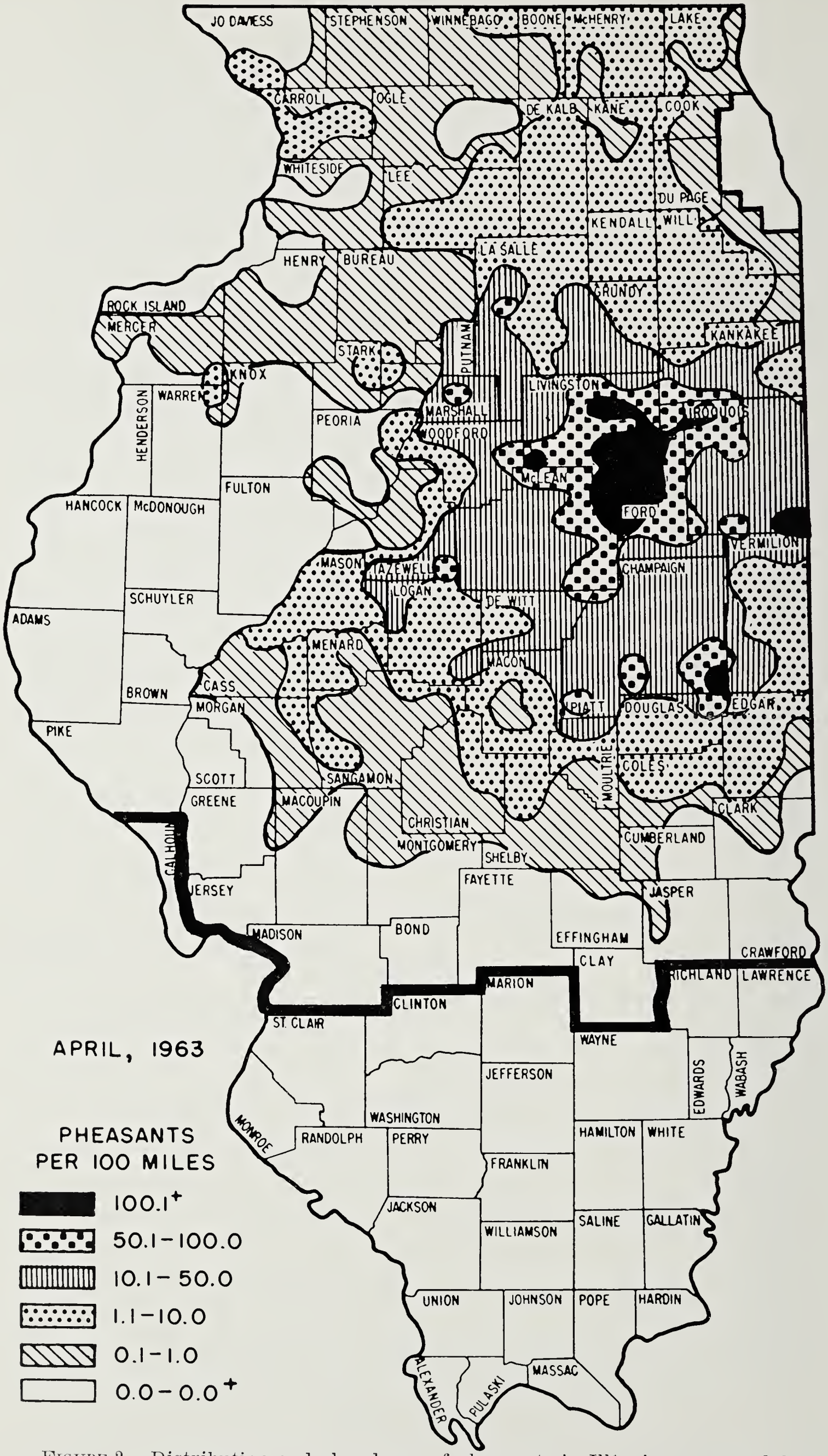

FIGURE 2.—Distribution and abundance of pheasants in Illinois as mapped from data (township) obtained through a rural mail carrier census, April, 1963. Counties below the heavy line were not censused.

which 56.4 and 99.1 birds were observed per 100 miles of driving in 1958 and 1963.

Perhaps the most interesting and notable increase in the abundance of pheasants in Illinois between 1958 and 1963 occurred in the contiguous block of counties including Piatt, De Witt, Moultrie, and Macon, which lie immediately south of McLean County and southwest of Champaign County (Table 2 and Fig. 2). The number of pheasants observed in these four counties nearly quadrupled between 1958 and 1963.

Pheasants declined in abundance *throughout* northern and northwestern Illinois between 1958 and 1963 (Fig. 1 and 2); these regions were characterized by secondary centers of abundance in the late 1940's (Greeley, et al. 1962, p. 16). The most notable decreases in abundance occurred in Stephenson, Boone, Jo Daviess, McHenry, De Kalb, Lee, Winnebago, and Kendall counties; less than 1 pheasant per 100 miles was reported from several of these counties in April, 1963 (Table 2).

The abundance of pheasants along the southern and southwestern fringe of the contiguous pheasant range in Illinois declined or remained unchanged between 1958 and 1963, which indicated that the bird had not spread southward or westward into unoccupied range. Pheasants observed in this marginal portion of the Illinois range numbered less than 1 pheasant per 100 miles in 1958 and 1963.

Discussion

Major changes in the abundance of pheasants within their range are not uncommon. One of the most spectacular shifts in pheasant abundance occurred in the plains and prairie states (North Dakota, South Dakota, Nebraska, Minnesota, and Iowa) during the 1940's (Kimball, Kozicky, and Nelson 1956, pp. 207-212). These population shifts centered about a nucleus of abundance located in eastern South Dakota; gains and losses in abundance occurred both east and west of this nucleus.

In Illinois, the major center of pheasant abundance has been located in the east-central sector of the state since the bird established itself there in the mid-1930's (Greeley, et al. 1962, pp. 13-16). In the late 1940's and early 1950's, secondary centers of abundance were to be found in sectors of northern Illinois; these secondary centers no longer existed by 1963. Whereas abundance declined in northern Illinois after the early 1950's, remarkable increases in abundance occurred south and southwest of the east-central center of abundance during the late 1950's and early 1960's. Thus, in Illinois, population shifts have centered about the nucleus of pheasant abundance in east-central Illinois.

The causes for major shifts in the abundance of pheasants within their range are not well understood. In Illinois, the increase in the abundance of pheasants in Ford County, in the east-central sector of the state, during the late 1950's and early 1960's was attributed partially to increased survival of hens and not to increased production of young by individual hens (Ronald F. Labisky, Illinois Natural History Survey, unpublished data). Similar ecological data for other portions of the Illinois pheasant range are not avail-

able. Kimball, et al. (1956, p. 212) concluded that "environmental changes appear to have been an important factor in bringing about the pheasant population fluctuations and shifts in the plains and prairie pheasant island; but some other factor or factors also appear to have exerted an influence."

Whether population shifts among pheasants are caused solely by the cumulative effects of so-called normal annual fluctuations is questionable. The suddenness and magnitude of major changes in the abundance of pheasants within their range certainly can not be explained fully by our present knowledge of accompanying changes in the environmental complex.

In Illinois, rural mail carrier censuses of pheasants will be conducted at intervals of 5 years, if possible, to determine changes in the distribution and abundance of this bird. Such periodic censuses of pheasants over a span of many years may enable ecologists to define not only the specific patterns in the temporal and spatial dispersion of this species but also the mechanisms underlying such population shifts.

Potential Problems

More pheasants were present in Illinois in 1963 than in 1958, but they were confined to a smaller portion of the state. The concentration of pheasants in east-central Illinois will probably begin to attract proportionately more hunters than in past years when other portions of the state also offered good pheasant hunting. If this pattern of high density pheasant populations on a restricted land area persists or becomes exaggerated in future years, conflicts between Illinois pheasant hunters and landowners in this region of high pheasant abundance could evolve.

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A STUDY OF SULFHYDRYL GROUPS IN CELL DEVELOPMENT

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ABSTRACT.—The distribution of –SH groups in the cellular components of the cleidoic grasshopper eggs and the increment of these chemical groups during embryogenesis has been determined using amperometric methods. The greatest concentration of the –SH groups was found in the microsome portion of the egg; this is in accord with other work which indicates that these subcellular particles are sites of bioorganic synthesis. A noted increase of –SH groups was observed when various reagents such as sodium borohydride, guanidine hydrochloride and Dupinol P.C. were used to break disulfide and hydrogen bonding.

Although the existence of the sulfhydryl group, sometimes called the mercaptan or thiol group, has been known for considerable time, only recently has the universal importance of the group in compounds come to be recognized. Since the discovery of this active group, its universal distribution in animal tissue has been clearly established. It is known that a large number of enzymes necessary for protein synthesis and metabolism depend on the presence of this –SH group for activity as proved by Barron and Seki (1952). The sulfhydryl group can be reacted by oxidation to form the disulfide group (–S–S–), or possibly by hydrogen bonding as postulated by Mazia (1956).

In recent years extensive research has been done to discover the role of the –SH group in cell production, enzyme activity, clotting of blood, protein denaturation and many other physiological activities. It has been known for some time that the –SH group is present in compounds known as the papinases or sulfyhdryl enzymes. These enzymes are activated by certain reducing agents and inactivated by aeration or other mild oxidation treatment. Whether these activating agents remove metal inhibitors or simply reduce the –S–S– to –SH is apparently not settled. It is customary to speak of free sulfhydryl groups and bound groups. Whether these bound groups are hydrogen bonded or disulfide forms is not settled and there is considerable evidence that possibly both exist at the same time.

The purpose of this investigation has been a quantitative distribution study of the sulfhydryl groups in cellular components using the cleidoic eggs of the grasshopper, *Melanoplus differentialis* as living material. Bodine (1929), (1932), Bodine et al. (1940), and Norman (1954), have shown that the sulfhydryl content increases after the egg is laid until it reaches the diapause stage.

An attempt has been made to study the increase in the sulfhydryl content by treatment of the so-called bound groups of the egg with the reagent sodium borohydride to reduce the –S–S– linkage. Other reagents, such as guanidine hydrochloride. Dupinol P.C. (a detergent) and urea have been studied. These are not strong enough to break the disulfide linkage but apparently exer-

cise a physical swelling effect to free the sulfhydryl groups bround by hydrogen bonding according to the postulations of Mazia (1956) and Boell (1935) working independently.

Materials and Methods

Grasshopper embryos of known age and temperature history were used. Samples containing 100 embryos per determination were homogenized in the cold for ten minutes, then transferred to an ordinary 250 ml. beaker for titration. A titration medium consisting of ethanol, ammonium hydroxide, ammonium nitrate and Versene was used. The resulting pH of this medium was determined with a Beckman pH meter to be 8.54. Embryos were titrated with silver nitrate, 5 x 10^{-4} M.

Samples of embryos and yolk were placed in a refrigerated centrifuge and centrifuged at speeds of 62,500 rpm to separate the nuclei, 200,000 rpm to separate mitochondria or large particles, and 370,000 rpm to separate the microsomes or small granules. Samples to give the quantity equivalent of 100 embryos and yolk were taken for determination and titration with silver nitrate. Another sample of 100 embryos and yolks were treated for 30 minutes with 15 mg of sodium borohydride and similar titrations were run after centrifugation. Other samples of like size were treated with 80% guanidine hydrochloride, with saturated urea solution, and saturated Dupinol P.C. for 30 minutes, then titrated after centrifugation.

Amperometric Titration Method.— In this particular study the amperometric method for determination of -SH groups, first described by Kolthoff and Harris (1946) and later modified by Benesch and Benesch (1950) for living material was used. This method is sensitive, highly specific, and not interfered with by any of the common amino acids, purines, pyrimidines, cozymase or ascorbic acid. A rotating platinum electrode, perfected by Wald and Brown (1952) for this type of apparatus was used. This method of titration is simple, as no E.M.F. need be applied to the cell which consists of an indicating and reference electrode. The current which flows through the cell during titration is read on a microammeter.

The rotating platinum electrode used was about 6 mm long and sealed in a 6 mm diameter soft glass tube. This electrode was rotated at 600 rpm by a synchronous motor. Electrical contact was made with the platinum electrode by placing mercury in the tube over it and dipping a wire into the mercury. A reference electrode was used which had a potential of -0.23 volts against the saturated calomel electrode. Electrical connection between the reference and rotating electrode was made by means of a salt bridge.

Silver Nitrate Method. — In titrating a mercaptan with silver nitrate, using a saturated calomel electrode as the reference electrode, the current was zero until the end point was reached. After this there was an excess of silver ions in solution. The diffusion current of the silver ion was measured with a microammeter, the diffusion current being proportional to the concentration of the silver ions in solution. When the current readings during titrations were plotted against vol-

ume of reagent added, two lines were obtained, which intersected at the end point. A 5 x 10^{-4} solution of silver nitrate prepared from a stock solution was used as the titrating agent. The titrating agent was delivered by means of a microburette. A commercial piece of apparatus, a Sargent "Ampot", using either the rotating platinum electrode or dropping mercury electrode, was used.

One tenth ml of 0.01 N ethylene diamine tetracetic acid, (Versene) was added to the titrating mixture. This acted as a powerful chelating agent and prevented the metal-catalyzed oxidation of soluble non-protein mercaptans in an alkaline titration medium as described by Benesch and Benesch (1950).

A sample to be determined was diluted to 40 ml with 22% aqueous ethanol. This solution was made up to 0.25 M in ammonium hydroxide and 0.05 M ammonium nitrate. The sample is titrated with the 5 x 10^{-4} M silver nitrate solution at the rotating electrode, and the -SH groups were removed by combination with the silver ions. The further addition of silver ions caused a flow of current which was proportional to the concentration of silver ions in solutions. Two or three readings of the microammeter were made before the end-point was reached. As long as the silver nitrate was not in excess, the current was zero. After the end-point was reached, the deflection of the ammeter corresponded to the diffusion currents of the excess silver ions. When the ammeter indicated that the end-point was passed, two or three small increments of silver nitrate were added and the current was read after each addition.

Results and Discussion

The results obtained by titration of untreated embryos showed that 52.08% of the sufhydryl groups were in the microsome fraction, 27.07% in the mitochondrial fraction, 16.70% in the cell nuclei, and 4.14% in the clear cytoplasm. The results that were obtained by treating the embryos with various reagents, followed by centrifugation and titration, demonstrated an increase in amount of titratable sulfhydryl in every instance. The greatest percentage of increase was with sodium borohydride which gave an increase of 37.50% and represented breaking of disulfide bonding. The results that were obtained by using reagents for breaking of hydrogen bonding demonstrated that guanidine hydrochloride with a 25.00% increase was the most effective and Dupinol P.C. with a 12.50% increase and saturated Urea with 7.25% increase in amount of titratable sulfhydryl were less effective.

The developing embryo in the grasshopper egg showed high cellular activity. This indicates that an increase of sulfhydryl groups is associated with periods of active growth. The abrupt rise of titer of -SH groups during development, occurs at the same time as morphogenetic growth and differentiation. This increase in sulfhydryl content parallels metabolic, mitotic and morphogenetic activity. The fact that the greater portion of the free sulfhydryl groups is located in the

microsome fraction supports the contention of Hammet (1929), Rapkine (1931), and Barron and Seki (1952) that the microsomes are concerned with protein, fat, and to some extent carbohydrate synthesis in the cell.

The increase in amount of titratable sulfhydryl after treatment with a strong reagent like sodium borohydride and the relatively weak or mechanical reagents such as guanidine hydrochloride, saturated urea, and Dupinol P.C. would indicate that in addition to occurring as free groups, the titratable sulfhydryls also occur as bond groups in at least two different types of linkages, the disulfide and hydrogen bonding.

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THE EFFECT OF ROTENONE ON OXYGEN UPTAKE BY LIVER MITOCHONDRIA OF THE BLUEGILL, *LEPOMIS MACROCHIRUS*

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ABSTRACT.—The effect of sodium amytal and rotenone on the alpha-ketoglutarate, oxidase, succinate oxidase, and adenosinetriphosphatase of bluegill liver mitochondria was investigated. Amytal and rotenone inhibited oxygen uptake with alpha-ketoglutarate as substrate but not with succinate. At amytal levels, which did not inhibit oxygen uptake, there was no effect on phosphate uptake; but at rotenone levels, which did not alter oxygen uptake, there was a decrease in phosphate uptake. Neither amytal nor rotenone increased the hydrolysis of adenosinetriphosphate; however, high concentrations of amytal and rotenone inhibited the hydrolysis.

Rotenone is widely used as a fish toxicant. This insecticide has been shown to reduce oxygen uptake by fishes (Danneel, 1933) and grasshoppers (Tischler, 1935). Later rotenone was thought to cause destruction of gill tissue (Danneel, 1933; Scheuring & Heuschmann, 1935) and to block the circulation in gill tissue (Hamilton, 1941). Oberg (1959) reported that in severe rotenone poisoning, the circulation in the gills was normal and the destruction of gill tissue was apparently due to secondary changes. Lindahl and Oberg (1961), studying the effect of rotenone on cellular respiration, reported that rotenone inhibited the uptake of oxygen in the presence of pyruvate and glutamate, but not in the presence of succinate as a substrate. Similar results had been reported by Fukami (1954) and Fukami and Tomizawa (1956) and Tomizawa and Fukami (1956).

Oberg (1961), using spectrophotographic techniques, demonstrated that rotenone inhibited the flow of electrons between diphosphopyridine nucleotide (DPN) and the cytochrome chain. Ernster (1957) reported that sodium amytal inhibited electron transfer between substrate and the cytochrome chain, and Chance (1958) indicated that the inhibition by amytal occurred between DPN and the cytochrome chain.

Since amytal and rotenone appear from the literature to have similar modes of action, the effect of amytal and rotenone on bluegill liver mitochondrial systems was invesigated.

MATERIALS AND METHODS

Native, wild bluegill, *Lepomis macrochirus,* were maintained in aerated aquaria at 25° C. Fish were killed by severing the spinal cord; the livers were excised and placed in cold 0.15 M sucrose. Excess sucrose was removed by blotting with filter paper; livers were weighed quickly. One to ten homogenates were prepared by adding nine volumes of pH 7.5 phosphate buffered 0.15 M sucrose in a glass Potter-Elvejhem type homogenizer with Teflon Pestle. Mitochondria were obtained from the homogenates at -2° C by centrifugation (Schneider & Hogeboom, 1950) in a Serval refrigerated centrifuge for 10 min-

utes at 21,000 x g after a preliminary centrifugation at 800 x g for 5 minutes to remove debris. (Note—Early results indicated that all the oxidative ability were obtained under these conditions.) The mitochondria were washed once and resuspended in original volume of buffered 0.15 M sucrose. One ml of tissue preparation was used.

For maximum oxygen and phosphate uptake with alpha-ketoglutarate as substrate the mitochondria were prepared and resuspended in homogenizing medium containing 0.001 M ethylene diamine tetraacetic acid (EDTA).

Mitochondria used in the adenosinetriphosphatase (ATPase) investigation were prepared in unbuffered 0.15 M sucrose.

Oxidation of the substrates was estimated by conventional manometric techniques (1957) in a Warburg apparatus at 25° C (Umbreit, et al., 1951). The main compartment contained 0.5 μmoles of adenosinetriphosphate (ATP), 0.05 ml of 1% cytochrome C, 10 μmoles of magnesium chloride, 30 μmoles of substrate, 0.05 ml 1% bovine serum albumin, and 0.15 M Trishydroxymethylamino methane (Tris) buffer pH 7.5 to give a total volume of 3.0 ml. The single side arm contained 60 μmoles of glucose and 0.1 ml of 1% hexokinase, prepared prior to use. Fluted filter paper, and 0.2 ml of 20% potassium hydroxide were placed in the center well. Air was the gas phase. After 5 minutes of incubation, the contents of the side arm were tipped into the main compartment, and zero time readings recorded after a total of 10 minutes incubation. Oxygen uptake was estimated at 10-minute intervals for a total period of 30 minutes.

With alpha-ketoglutarate as substrate, the reaction medium also contained 0.5 μmoles of adenosinediphosphate (ADP) and COA, and the preincubation period was 15 minutes.

The phosphate contents of the reaction media were estimated using essentially the procedures of Lowry and Lopez (1946), and color estimated using a Coleman Jr. spectrophotometer at 660 mμ. Phosphate uptake was determined by comparing the inorganic content of the reaction media with appropriate zero time samples prepared in 20 ml beakers.

The ATPase activity of freshly prepared mitochondria was investigated by estimating the release of inorganic phosphate from ATP in a reaction medium consisting of 0.05 ml of 0.1 M ATP, 0.02 or 0.05 ml of 0.1 M metal ion, all added as chloride salts, 0.2 ml of mitochondrial preparation, and Tris buffer pH 7.5, to give a total volume of 2 ml. The reaction media were incubated in 20 ml beakers for 15 minutes at 25° C in a Dubnoff metabolic incubator (1948). The enzyme reaction was stopped by transferring the contents of the reaction vessels into test tubes containing 1 ml of 5% trichloroacetic acid (TCA), and the phosphate content was estimated as indicated above.

The nitrogen content of all tissue preparations was estimated by direct Nesserlization of tissue digests (1955), and the color estimated at 425 mμ.

Oxygen data are expressed as Q_{o2} values ($\mu 10_2$/hr/mg N), and phos-

phate data as μmoles of PO_4/hr/mg N, and all values have been corrected for endogenous activity. The data presented are average values from two or more experiments.

Results and Discussion

The effects of amytal and rotenone on oxygen and phosphate uptake are summarized in Table 1. Succinate oxidation was increased in the presence of amytal and rotenone, whereas the alpha-ketoglutarate oxidation was severely inhibited. As the concentration of amytal was reduced, the inhibition of alpha-ketoglutarate oxidation was reduced; and at an amytal concentration of 0.81 x 10^{-7} g per ml of reaction medium, no effect on either oxygen uptake or phosphate uptake was observed. Likewise, a reduction of the rotenone concentration also reduced the inhibition of the oxidation of alpha-ketoglutarate; but in contrast to amytal at a rotenone level which did not alter oxygen uptake, there was approximately a 20% reduction in phosphate. Therefore, rotenone appears to have an additional effect on phosphate uptake not exhibited by amytal under the conditions described.

Table 1.—Effect of Amytal and Rotenone on Oxygen and Phosphate Uptake in the Presence of Succinate and Alpha-ketoglutarate.

With Succinate

	g/ml	μ liters O_2 /hr/mg N		μmoles PO_4 /hr/mg N	
Amytal . . .	0.41×10^{-3} g	191	99	34	13
Rotenone . .	0.41×10^{-6} g	448	283	70	26

With Alpha-ketoglutarate

	g/ml	μ liters O_2 /hr/mg N		μmoles PO_4 /hr/mg N	
Amytal . . .	0.81×10^{-8} g	181	176	56	54
	0.41×10^{-3} g	0	176	4	54
Rotenone . .	0.66×10^{-7} g	192	204	38	48
	0.66×10^{-6} g	0	204	6	48

The total amount of phosphate in the reaction medium is the result of the total amount of inorganic phosphate incorporated altered by the quantity of inorganic phosphate which may be released from tissue organic phosphates, such as ATP, or by the inhibition of phosphate uptake. To determine if the net decrease in phosphate uptake might be due to the effect of rotenone on the hydrolysis of tissue phosphates, the effect of amytal and rotenone on the mitochondral ATPase was estimated. These results are summarized in Table 2. Neither amytal nor rotenone at the levels presented in Table 2 increased the hydrolysis of ATP; but higher concentrations of rotenone inhibited the hydrolysis of ATP. This would indicate that the effect of rotenone on phosphate uptake would be at some point or points during the conversion of inorganic phosphate into tissue organic phosphate. These data agree with the data presented by Chance and Hollunger (1963) and Ernster et al. (1963) whose data indicated that

TABLE 2.—Effect of Amytal and Rotenone on Mitochondria ATPase.

metal ion	μmoles of metal added to reaction medium	Amytal 3.7×10^{-3} g/ml of reaction medium		Rotenone 3.9×10^{-6} g/ml of reaction medium	
		μmoles PO_4/hr/mg N		μmoles PO_4/hr/mg N	
Zinc.....	2	14.3	22.9	49.1	48.4
Cadmium...	2	39.2	39.2	64.7	65.6
Manganese..	2	47.7	41.6	35.1	36.0
Magnesium..	2	42.0	43.2	18.9	20.3
Calcium.....	5	23.2	25.8	19.0	17.1

rotenone interfered at some point in the transfer of energy. Also, the point of inhibition or mechanism of action of rotenone has yet to be elucidated.

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KINETICS OF THE REDUCTION OF PEROXODISULFATE ION BY BENZOIC ACID

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ABSTRACT.—The kinetics of the reduction of peroxodisulfate ion by benzoic acid with silver ion as a catalyst has been studied by iodometric determination of the peroxodisulfate ion. Hydrogen peroxide formed during the reaction was destroyed by the use of catalase. Two concurrent reactions, one first order and one second order with respect to peroxodisulfate, are involved.

Peroxodisulfate ion in the presence of silver ion, as a catalyst is capable of oxidizing many benzene ring compounds (Bacon, 1960) with the formation of a resinous material. Since benzoic acid presented fewer analytical difficulties than most of the other benzene derivatives, it was chosen for this study.

Preliminary studies showed that the rate of the reaction was zero order with respect to benzoic acid and first order with respect to silver ion. This was in agreement with earlier investigations which showed that the reduction rate is independent of the concentration and character of the reducing agent (Cone, 1945; Gupta, 1959).

The reaction was nearly first order with respect to peroxodisulfate ion but careful examination of the data indicated that two simultaneous reactions were taking place. The first order reaction may be represented by the following mechanism:

$$(1)\quad S_2O_8^{2-} + Ag^+ \longrightarrow \left[\text{activated complex}\right] \longrightarrow SO_4^{-\cdot} + Ag^{2+} + SO_4^{2-}$$

$$(2)\quad Ag^{2+} + H_2O \longrightarrow H^+ + Ag^+ + HO\cdot$$

$$(3)\quad SO_4^{-\cdot} + H_2O \longrightarrow SO_4^{2-} + H^+ + HO\cdot$$

Equation (1) is the slow reaction and is rate determining.

The second reaction was second order and can be represented by the folowing equation:

$$(4)\quad 2S_2O_8^{2-} + 3H_2O \longrightarrow H_2O_2 + [O] \rightarrow 4HSO_4^-$$

The differential equation for the two simultaneous reactions is shown below:

$$(5)\quad \frac{d[S_2O_8^{2-}]}{dt} = -k_1\,[S_2O_8^{2-}] - k_2\,[S_2O_8^{2-}]^2$$

which on integration yields:

$$(6)\quad \log\left[\frac{[S_2O_8^{2-}]_0}{[S_2O_8^{2-}]t}\right]\left[\frac{k_1 + k_2\,[S_2O_8^{2-}]t}{k_1 + k_2\,[S_2O_8]_0}\right] = \frac{k_1\,t}{2.303}$$

In order to calculate k_2, the first order rate constant, k_1 had to be known. The first order rate constant was taken from another work (Cone, 1945) in which the rate constant of the first order reaction was found by determining the concentration of the product oxidized by peroxodisulfate ion. Cone's work would have not detected any side reactions involving peroxidisulfate ion.

The value of the first order rate constant is 0.447 min^{-1} at 35° (Cone, 1945) and a calculated value, using the Arrhenius equation, of 0.650 min^{-1} at 44.55°. With the use of these rate constants calculations were made to determine the concentration of the peroxodisulfate ion if only the first order reaction had occurred. From these values are substracted the concentrations of peroxodisulfate ion determined experimentally. The difference between these two values is the concentration of peroxodisulfate ion which was reduced by means of the second order reaction.

If the left side of equation 6 is plotted against time, by use of experimental data (at 34.91°C) from Table 1, a linear plot is observed as

TABLE 1.—Data and Calculated Values for the Determination of the Second Order Rate Constant at 34.91°C and 44.55°C.

Data at 34.91°C

Time (min.)	A	B	C	D
0	9.750	9.750	0.000	....
30	9.092	9.621	0.529	0.147
60	8.577	9.499	0.922	0.153
90	8.126	9.365	1.239	0.150
120	7.669	9.241	1.572	0.152
150	7.242	9.118	1.876	0.153
180	6.858	8.995	2.137	0.152
210	6.517	8.878	2.316	0.149
240	6.154	8.758	2.604	0.150
270	5.816	8.642	2.826	0.150

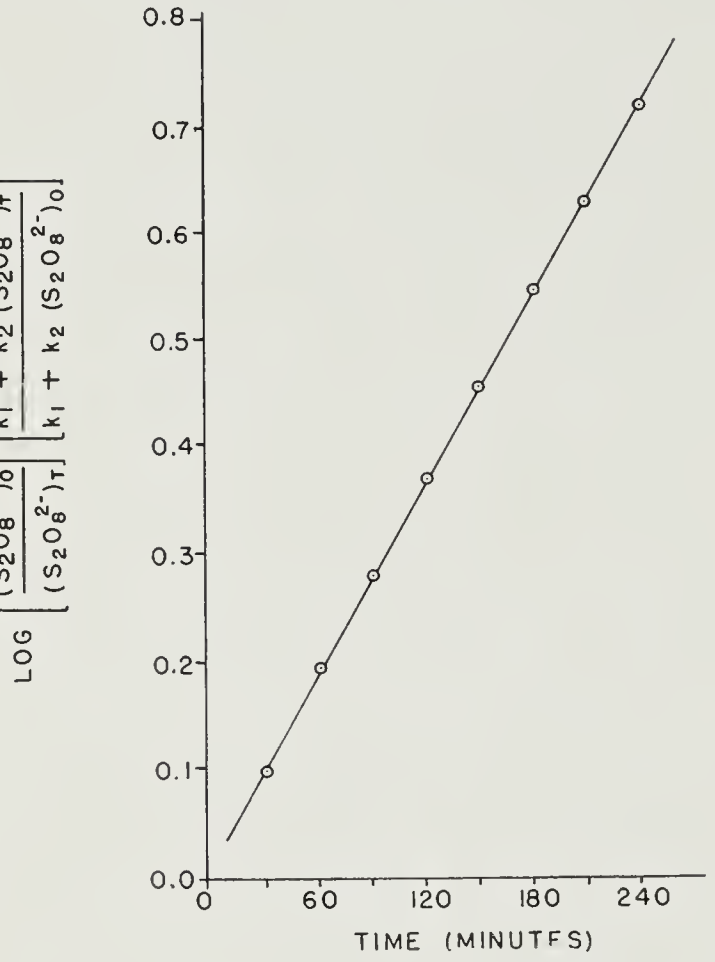
Data at 44.55°C

Time (min.)	A	B	C	D
0	9.875	9.875	0.000	....
30	8.471	9.648	1.213	0.437
60	7.344	9.498	2.154	0.453
90	6.449	9.314	2.865	0.448
120	5.639	9.134	3.495	0.453
150	4.963	8.958	3.995	0.451
180	4.348	8.785	4.437	0.453
210	3.852	8.615	4.763	0.444
240	3.362	8.449	5.087	0.443

Code to Table: A—Experimental molarity of the peroxodisulfate ion x 10^3; B—Molarity of peroxodisulfate ion calculated from Cone's first order rate constant; C—Molarity of peroxodisulfate ion consumed by the second order reaction; and D—Reaction rate constant, k_2, for the second order reaction in liter per mole per minute.

The concentration of silver ion in both cases is 1.00 millimolar.

FIGURE 1.—A time dependent plot from data taken from Table 1 at 34.91°C showing remarkable linearity.



is shown in Figure 1. A similar plot is obatined if one uses the data at 44.55°.

The progress of the reaction was followed by determining the oxidizing power of the solution by an iodometric titration of aliquot samples. Aliquots were withdrawn at intervals of 30 minutes. Before each aliquot was analyzed one milliliter of a 0.5% solution of catalase was added. Catalase is known to be specific for the decomposition of hydrogen peroxide (Beers, 1954). The aliquot sample was then flushed with nitrogen for 60 seconds to eliminate oxygen from the solution.

Preliminary experiments showed that the enzyme did not interfere with the analysis of the peroxodisulfate ion. This method is a quantitative method for determination of peroxodisulfate ion in the presence of hydrogen peroxide.

Debye-Huckel calculations involving ionic strength did not correct the experimental data so that it would follow a simple first order rate law. Deviations from first order data are much too great to involve only ionic strength corrections.

ACKNOWLEDGMENTS

The initial phases of this work were done at the University of Idaho, Moscow, Idaho, under the direction of Dr. W. H. Cone who has recently retired from the Department of Chemistry.

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NEWS AND COMMENTS

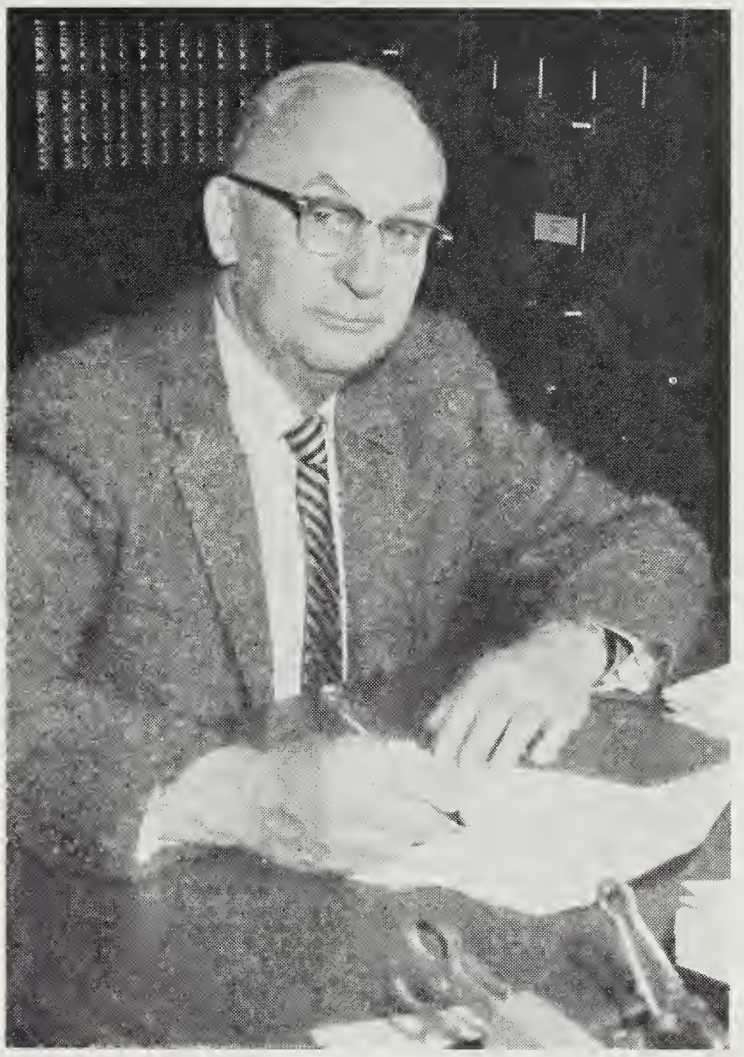
January is one devil of a time to write comments to be read in sunny June. I do not feel "sunny." I am still finding "goofs" in that big, fat issue that came out at the end of last year. The latest discovery is the inverted formula on page 266. Somewhere and sometime after the author read the galley the inversion took place. However, you victims of my failures may now rejoice in learning that the printer committed a big spelling "goof" on the cover of one of MY reprints.

Manuscripts are coming into the editorial office (a carton in one corner of my workroom) at a terrifying rate. As long as the budget will stand the strain I will do all I can to get every acceptable paper into the Transactions as soon as possible.

Treasurer Ashby tells me that our membership is growing. He had to order several thousand new membership application forms a few days ago. So get out and rustle up some more members. We need the dues to help pay for the Transactions. What am I saying? More members result in more papers; more papers make bigger Transactions; bigger Transactions need more members; more members mean . . . . . Oh well, go out and get the new members and we'll see where it all ends.

Milton D. Thompson, Director of the Illinois State Museum, announced the retirement of Thorne Deuel on December 31, 1964. Dr. Deuel, research scientist for the past two years and former Museum Director, retired after 27 years of state service.

The Museum Board of Advisors and the Director of Registration & Education paid high tribute to Dr. Deuel at their Board meeting on December 18th by passing a resolution which appointed him Museum Director, Emeritus, and Research Associate in Anthropology, of the Illinois State Museum.



THORNE DEUEL

Dr. Deuel, a nationally known anthropologist, pioneered the development of midwestern archaeology with Fay-Cooper Cole, Georg K. Neumann and others. His contributions in the Museum field have been equally as outstanding, resulting in his ultimate goal to make the Illinois State Museum one of national importance and to acquire a new Museum building for the State.

Dr. Deuel will continue the long-term research project in the science of culture, which he has been actively engaged in for the past two years.

NOTES

PORCUPINE FROM THE OZARK HIGHLANDS OF MISSOURI

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ABSTRACT.—An incomplete left jaw of a porcupine (*Erethizon dorsatum*), found in an archaeological rockshelter site in Phelps County, Missouri, constitutes the second prehistoric record of porcupine for Missouri.

A part of the lower left jaw of a porcupine, *Erethizon dorsatum*, was found during periodic excavations in 1961-62 at the Tick Creek Cave Site, 12 miles west of Rolla, Phelphs County, Missouri. The jaw was that of a juvenile animal; the premolar had not yet erupted above the rim of the alveolus. Approximately one-half of the ventral margin had been broken away, apparently during the digging operations and the incisor, M_3 and about half the ramus were missing. A series of light, transverse skinning cuts occurred at the base of the coronoid fossa, indicating the animal had been taken and skinned by the Late Woodland occupants (800-1300?A.D.) of this rockshelter. The presence of only this one element in over 40,000 bones may or may not indicate its former abundance in this area.

The Ozark Highland represents an old, deeply dissected plateau which now appears as hills with steep intervening valleys cut by numerous clear streams arising in the higher elevations. The original mesophytic forest cover was an oak and hickory type—a western extension of the large deciduous forests of eastern United States — interspersed with short-leaf pine. This environment formed suitable habitat for a variety of vertebrate species, particularly mammals, which were used extensively by the Indians occupying this area. In order of decreasing abundance the following mammal remains were also recovered at this site: white-tailed deer, raccoon, squirrels (*Sciurus* spp.), cottontail, elk, striped skunk, gray fox, beaver, canids and woodchuck. Bones of the turkey and turtles (especially *Terrapene*) were abundant.

Prior to the recovery of the specimen reported here from the Tick Cleek Cave Site, the only evidence for the former occurrence of porcupine in Missouri were two lower jaws recorded by Simpson (1949) from Cherokee Cave in St. Louis along with a mixture of Pleistocene (peccary, armadillo) and recent (black bear, raccoon, beaver and porcupine) forms. These records and the bones of porcupine from a cave in Monroe County, Illinois (Parmalee, Bieri and Mohrman, 1961) established the former occurrence of *E. dorsatum* southward along the Mississippi River bluffs in the central Midwest.

The prehistoric occurrence of porcupine in Phelps County is noteworthy in that it fills a gap in the known range of this species in the central Midwest region. Judging from the distributional map presented by Hall and Kelson (1959), this Ozark Highlands animal may be *Erethizon d. dorsatum* and represents a southwestern extension of this northeastern subspecies. Cockrum (1952) records *Erethizon d. bruneri* from Johnson County, Kansas, a distance of approximately 160 miles northwest of the Phelps County, Missouri locality. The prairie regions of northern and western Missouri may well have formed a natural barrier separating the two forms.

Extreme southern and western range extensions for the porcupine in the eastern half of the United States have been established on the basis of remains from caves (Kellogg, 1939; Parmalee, Bieri and Mohrman, 1961) and archaeological sites (Barkalow, 1961). There were no historic accounts of the rodent from these areas and it appears the porcupine disappeared from these farthest localities prior to the coming of the white man. Possibly the xerothermic period (3,000-1,000 B.C.) of warm and dry climate may have been an influencing factor, directly and indirectly, reducing or eliminating small populations at the range extremities. Although the

topography and vegetation type in the regions from which these prehistoric marginal records occurred still appear to be suitable habitat for the porcupine, it was apparently unable to survive climatic/vegetation change or possibly hunting pressure by early man in many areas of its former range in eastern United States.

I would like to thank Mr. Ralph G. Roberts and Mr. Jack Scrivner of Rolla who undertook most of the field work at Tick Creek Cave and made the faunal materials available to me for study.

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A SECOND OF *HEMIDACTYLIUM SCUTATUM*, THE FOUR-TOED SALAMANDER, IN KENTUCKY

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Abstract.—The occurrence of the salamander *Hemidactylium scutatum* in Mammoth Cave National Park is reported, along with information on the probable date of egg deposition.

Five females and eggs of *Hemidactylium scutatum* were observed on May 1-2, 1959 and April 21, 1961 near the older campground in Mammoth Cave National Park. The site is along the bank of an intermittent stream which runs through open, deciduous woods at an elevation of 740 feet on the northwest edge of Mammoth Cave Ridge, Edmonson County, Kentucky.

The female found on May 1 was coiled on top of a nest of eggs under damp leaves and approximately six inches above the water level of a pool in the stream. On May 2, three more females and their eggs were found nearby under a mat of moss about one foot above the water level; all were in separate nests within an area of about one-half square foot. Two years later, on April 21, 1961, a female and eggs were found in the same locality.

One female (44 mm body length, 62 mm total length), now University of Illinois Museum of Natural History no. 57547, and a few eggs were returned to the laboratory. Five eggs were kept at about 20° C and hatched three days later into larvae 14 mm long. Deposition of these eggs probably occurred in early to middle March, if their incubation period is comparable to that of 52-53 days recorded in New York (Bishop, 1941). The large size of the larvae hatched in the laboratory indicates that they did not hatch prematurely. The New York larvae averaged 12.5 mm at hatching, and ranged from 11-14 mm.

Since the range of *H. scutatum* is strikingly discontinuous along its southern and western limits (Neill, 1963), individual records are of considerable interest. This species was not included in Hibbard's (1937) list of amphibians and reptiles in the proposed Mammoth Cave National Park. Except for Green's (1941) report of *H. scutatum* in Carter County, about 185 miles to the northeast, no record of its occurrence in Kentucky has been reported. In his contribution to the American Society of Ichthyologists and Herpetologists' Catalogue. Neill (1963) showed records in southwestern Indiana and at the type-locality, Nashville, Tennessee. On his range map, a continuous range was indicated between these two localities; however, no record in central Kentucky was actually known (Neill, pers. comm.).

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THE DETERMINATION OF TOTAL CHLOROPHYLL IN METHANOL EXTRACTS

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Abstract. — The colorimetric determination of chlorophyll is dependent upon the efficiency of the solvent used for extraction. Using reported absorption coefficients for chlorophylls a and b in methanol, we have derived the following forumla for chlorophyll in mg per liter of extract:

$$C = C_a + C_b = 25.5\ D_{651} + 4.0\ D_{664}.$$

A critical step in procedures for the determination of chlorophyll in plant tissues is that of extraction. In work with apple leaves, methanol has been found to be a much more efficient chlorophyll solvent than is acetone. Compton and Boynton (1945) developed a method for determining chlorophyll in methanol extracts of apple leaves. MacKinney (1941) and Harris and Zscheile (1943) have determined the absorption coefficients of chlorophylls a and b in several solvents including methanol and acetone. Arnon (1949) used the absorption coefficients (K values) of chlorophyll in acetone as reported by MacKinney, to derive the following formula for the estimation of total chlorophyll in acetone extracts in plant tissues.

(1) $C = C_a + C_b = 20.2\ D_{645} + 8.02\ D_{663}$

where C_a and C_b are chlorophylls a and b in mg/liter, and D is the optical density of extracts at wavelengths 645 and 663 millimicrons.

Arnon's formula, although it has been widely used for chlorophyll studies, is applicable only for acetone solutions because of the solvent effect on absorption coefficients, MacKinney (1941). The use of methanol for the extraction of chlorophyll from apple leaves necessitates a change in Arnon's formula for the estimation of total chlorophyll. Using MacKinney's absorption maxima of 664 and 651 millimicrons with K values of 74.5 and 36.4 for chlorophylls a and b, we have modified Arnon's formula for chlorophyll extracted in methanol.

The following simultaneous equations of Arnon's with appropriate values for methanol as a solvent are presented.

(2) $D_{664} = 74.5\ C_a + 18.3\ C_b.$

(3) $D_{651} = 27.6\ C_a + 36.4\ C_b.$

From equation (3):

$$(4)\quad C_a = \frac{D_{651} - 36.4\ C_b}{27.6}$$

Substituting into equation (2) and solving for C_b we obtain:

(5) $C_b = 0.0338\ D_{651} - 0.0125\ D_{664}.$

Substituting this equation for C_b in equation (3) and solving for C_a:

(6) $C_a = 0.0165\ D_{664} - 0.0083\ D_{651}.$

Therefore, total chlorophyll in g/liter is:

(7) $C = C_a + C_b$

$C = 0.0255\ D_{651} + 0.0040\ D_{664}$

or:

(8) $C = 25.5\ D_{651} + 4.0\ D_{664}$ mg/liter of chlorophyll in methanol.

The procedure used is as follows. Sampling and preparation are carried out under red light. Ten to 30 discs of 11-12 mm diameter are punched from fresh leaves and their total fresh weight is recorded. The discs, covered with watch glasses, are left for 15 to 18 hr in 50 ml of 99.8% methanol. At the end of this time the chlorophyll is leached into the methanol, leaving the discs practically colorless. Five ml of the 50 ml methanol extracts are measured at 651 and 664 millimicrons in a Beckman model DU spectrophotometer. Substituting the density values (D) of these two readings in equation (8) one can estimate the methanol soluble chlorophyll content of apple leaves. Results are expressed as mg/disc, mg/g of fresh wt, or mg/cm^2 of leaf surface.

Ozerol (1964) has found that total chlorophyll values, as described above,

correlate well with both leaf nitrogen and spectral reflectance curves of intact leaves.

Acknowledgment

The authors express their thanks to Dr. Govindjee, Photosynthesis Laboratory of the University of Illinois, for his valuable suggestions.

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A FIRST REPORT OF *AEDES INFIRMATUS* DYAR AND KNAB IN ILLINOIS

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Three females of *Aedes infirmatus* Dyar and Knab were collected in the Mermet Waterfowl Management Area, Massac County, Illinois. The first specimen was collected May 27, 1964 as a part of an intensive study of the ecology of arthropod-borne viruses in southern Illinois. The three specimens were collected as they came to feed on man. This research was supported by U. S. Public Health Service Grant No. CC 00037.

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A COLLECTION OF AMPHIBIANS AND REPTILES IN SOUTHERN ILLINOIS

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Abstract. — Fifty-seven species and subspecies of amphibians and reptiles were collected in Johnson, Massac, Pope and Pulaski counties in southern Illinois. New county records were established for five forms.

During the past several years, representatives of the Cooperative Wildlife Research Laboratory have collected amphibians and reptiles in southern Illinois with major emphasis on the two southern-most tiers of counties. This paper reflects collecting primarily in the southern tier of townships (Cache, Vienna and Grantsburg) of Johnson County; also included are findings for a few localities in Massac, Pope and Pulaski counties. Emphasis was placed on this region of Johnson County because of the great variety of habitats afforded. In many respects it is similar to the Pine Hills Area in Union County whose herpetofauna has been reported (Rossman 1960).

The topography of this region represents the Shawnee Hills section of the Interior Low Plateaus Province and the Coastal Plain Province (Leighton *et al.* 1948). Where the Shawnee Hills meet the Coastal Plain Province there are extensive rock outcroppings and precipitous bluffs at the bases of which are springs and inconspicuous, shallow caves. The adjacent and interior bottomlands feature the Cache River and

its tributaries, Bay Creek, and several woodland sloughs the largest of which is Little Black Slough. According to forest types (Vestal 1931), the upland features the Southern Division, and the bottomland, the Tertiary Division. Herpetofaunal divisions by Smith (1961) classify the upland region as Shawnee Hills, an area rich in number of species and individuals, and the lowland as Austroriparian, whose herpetofauna is strongly influenced by forms characteristic of the Gulf Coast. As evidenced by the above ecological divisions, this region of southern Illinois provides a wide variety of faunal niches. Our collection of 57 representatives of the herpetofauna substantiates this conclusion as it represents over 50 per cent of all the forms reported for the entire State (Smith 1961).

A total of 55 collection sites were included (Table 1); by counties these were: Johnson 47, Massac 3, Pope 2, and Pulaski 3.

No attempt was made to collect every specimen observed; only a representative sample was actually preserved. In many instances where only a few specimens were found, only one was preserved. However, in some cases the number collected represented all that were observed or that could be captured. All specimens collected and preserved have been deposited in the herpetological collection of the Cooperative Wildlife Research Laboratory or in the collections of the Department of Zoology.

On the basis of the numbers observed and collected, an indication has been made of the relative abundance (common, uncommon, rare) of each species or subspecies. This reflects wide occurrence (generally) or local occurrence (locally) with reference to the finding of specific forms in available and seemingly suitable habitats.

In the list of representatives which follows, the numbers recorded in conjunction with each county refer to the collection sites with the same numbers as presented in Table 1. Scientific terminology follows that of Smith (1961).

LIST OF FORMS

Caudata: Fourteen of the 19 species and subspecies recorded for Illinois (Smith 1961) are represented in our collection; only *Desmognathus fuscus*, which occurs in southern Illinois (Rossman 1958), was not recorded.

Cryptobranchus alleganiensis alleganiensis (Daudin)—Hellbender. Massac County: 51. Rare. One specimen collected near Joppa from drift wood at edge of Ohio River by Wayne Greer, June 2, 1960. Stein and Smith (1959) reported only three preserved specimens for Illinois; the latest record was April 15, 1956 from the Ohio River near Metropolis, Massac County.

Ambystoma maculatum (Shaw)—Spotted Salamander. Johnson County: 2; Massac County: 48. Locally fairly common.

Ambystoma opacum (Gravenhorst)—Marbled salamander. Johnson County: 2, 5, 12, 13, 22, 30, 38, 39; Pope County: 52, 53; Massac County: 48. Locally common.

Ambystoma talpoideum (Holbrook)—Mole salamander. Johnson County: 44; Pope County: 53; Rare; single specimen from each of the counties. This represents the first record for Pope County; Smith (1961) reported it from Alexander, Jackson, Union, and Johnson counties.

Ambystoma texanum (Matthes)—Smallmouthed salamander. Johnson County: 12, 46, 47; Massac County: 48. Generally uncommon.

Ambystoma tigrinum tigrinum (Green) Eastern tiger salamander. Johnson County: 6, 26. Generally uncommon.

Notophthalmus viridescens louisianensis (Wolterstorff) — Central newt. Johnson County: 10; Pope County: 52, 53. Generally uncommon.

Eurycea bislineata rivicola Mittleman —Midwest two-lined salamander. Pope County: 52. Locally rare.

Eurycea longicauda longicauda (Green) —Long-tailed salamander. Johnson County: 1, 5, 9, 10, 12, 17; Pope County: 52. Fairly common.

Eurycea lucifuga Rafinesque — Cave salamander. Johnson County: 1, 5, 9, 10, 13, 14, 17, 35, 39, 45; Massac County: 48. Common.

Plethodon dorsalis Cope—Zigzag salamander. Massac County: 48; Pope County: 53. Uncommon.

Plethodon glutinosus glutinosus (Green) —Slimy salamander. Johnson County: 1, 2, 5, 7, 9, 10, 12, 13, 14, 16, 22, 28, 31, 47; Massac County: 48; Pope County: 53. Very common.

Necturus maculosus maculosus (Rafinesque)—Mud puppy. Johnson County:

6, 32. Locally fairly common. One adult was caught by E. H. Compton while fishing in Cache River; there were many reports of previous catches and observations by fishermen in this river. On April 23, 1960, the junior author collected six larvae in a farm pond which contained "hundreds".

Siren intermedia nettingi Goin—Western lesser siren. Johnson County: 11. Generally rare.

Salientia: Twelve of 21 representatives for Illinois as reported by Smith (1961) were collected by us.

Bufo americanus charlesmithi Bragg—Dwarf American toad. Johnson County: 11, 22; Pope County: 52. Generally uncommon.

Bufo woodhousei fowleri Hinckley—Fowler's toad. Johnson County: 2, 10, 12, 27, 47. Very common.

Acris crepitans blanchardi Harper—Blanchard's cricket frog. Johnson County: 1, 7, 10, 12, 15, 16, 19, 22, 46, 47. Very common.

Pseudacris triseriata feriarum (Baird). Upland chorus frog. Johnson County: 10, 19, 32, 38, 46, 47; Pope County: 52, 53; Pulaski County: 55. Fairly common.

Hyla avivoca avivoca Viosca—Western bird-voiced treefrog. Johnson County: 11, 38. Locally fairly common. This represents the first record for this county; Smith (1961) reported it for only Alexander, Union and Jackson counties.

Hyla cinerea (Schneider) Green treefrog. Johnson County: 11, 47. Very rare as only one specimen was found in each locality. This is believed to be the first record from this county; Smith (1961) shows it for only Alexander and Union counties.

Hyla crucifer crucifer Wied—Northern spring peeper. Johnson County: 47. Generally uncommon. Seemingly there is an almost void of this species in the central sector of extreme southern Illinois.

Hyla versicolor versicolor Le Conte—Eastern gray treefrog. Johnson County: 3, 10, 11, 19, 46, 47. Fairly common.

Rana areolata circulosa Rice & Davis—Northern crayfish frog. Johnson County: 27. Generally rare; only one specimen was collected. There are few records for extreme southern Illinois (Smith 1961).

Rana catesbeiana Shaw — Bullfrog. Johnson County: 7, 15, 28, 30; Massac County: 49. Generally common.

Rana clamitans melanota (Rafinesque) Green frog. Johnson County: 33, 34, 47. Locally uncommon.

Rana pipiens sphenocephala Cope. Southern Leopard frog. Johnson County: 7, 8, 12, 18, 22, 28, 39, 47. Very common.

Testudines: Seven of the 17 representatives reported by Smith (1961) for Illinois were recorded by us; however, we did not make deliberate effort to collect turtles.

Chelydra serpentina serpentina (Linnaeus) Common snapping turtle. Johnson County: 11, 32, 46, 47. Locally very common.

Sternothaerus odoratus (Latrielle)—Musk turtle. Johnson County: 11, 30, 47. Locally fairly common.

Kinosternon subrubrum subrubrum (Lacépède) — Mud turtle. Johnson County: 2, 11, 30, 47. Locally fairly common. This probably represents the first record for this county and one of very few records for southern Illinois (Smith 1961).

Terrapene carolina carolina (Linnaeus) —Eastern box turtle. Johnson County: 2, 32. Generally very common.

Chrysemys picta marginata Agassiz—Midland painted turtle. Johnson County: 11, 30, 32, 47. Locally fairly common.

Pseudemys scripta elegans (Wied)—Red-eared turtle. Johnson County: 11, 30, 47. Locally fairly common.

Trionyx spinifer spinifer Le Sueur—Eastern spiny softshell. Johnson County: 32. Locally fairly common.

Squamata (Sauria): Five of six representatives reported for Illinois (Smith 1961) were collected.

Sceloporus undulatus hyacinthinus (Green) Northern fence lizard. Johnson County: 1, 2, 27, 28, 32; Pope County: 53; Pulaski County: 55. Generally very common.

Cnemidophorus sexlineatus sexlineatus (Linnaeus) — Six-line racerunner. Johnson County: 27, 32, 38. Locally fairly common. These records represent the first for this county; Smith (1961) reports it in this area only from counties bordering the Ohio River in extreme southeastern Illinois.

Scincella laterale (Say)—Ground skink. Johnson County: 2, 10, 14, 15, 25, 27. Generally very common.

Eumeces fasciatus (Linnaeus)—Five-lined skink. Johnson County: 9, 15, 26, 27, 32, 37; Massac County: 50. Locally very common.

Eumeces laticeps (Schneider) Broadheaded skink. Johnson County: 2. Generally uncommon.

Squamata (Serpentes): Nineteen of 46 species and subspecies reported by Smith (1961) for Illinois were represented in our collection.

Carphophis amoenus helenae (Kennicott)—Midwest worm snake. Johnson County: 1, 13, 34. Generally fairly common.

Farancia abacura reinwardti Schlegel—Western mud snake. Johnson County: 11. Generally uncommon.

Diadophis punctatus edwardsi (Merrem) Northern ringneck snake. Johnson County: 13; Pope County: 53. Generally uncommon.

Heterodon platyrhinos Latrielle—Eastern hognose snake. Johnson County: 15, 21, 29. Generally fairly common.

Opheodrys aestivus (Linnaeus) Rough green snake. Johnson County: 20, 21, 40. Generally fairly common.

Coluber constrictor priapus x flaviventris Say — Eastern yellow-bellied racer. Johnson County: 3, 26; Massac County: 48. Generally very common.

Elaphe obsoleta spiloides Duméril, Bibron, & Duméril—Gray rat snake. Johnson County: 22, 23, 27. Generally very common.

Lampropeltis calligaster calligaster (Harlan)—Prairie kingsnake. Johnson County: 47; Massac County: 50. Generally rare. Seemingly this is the first record for Johnson County.

Lampropeltis getulus niger (Yarrow)—Black kingsnake. Johnson County: 13, 29; Pope County: 52. Generally fairly common.

Lampropeltis triangulum syspila (Cope) Red milk snake. Massac County: 48. Generally rare.

Thamnophis sirtalis sirtalis (Linnaeus) Eastern garter snake. Johnson County: 27; Pulaski County: 55. Locally fairly common.

Virginia valeriae elegans (Kennicott)—Western earth snake. Johnson County: 2. Generally rare.

Storeria occipitomaculata occipitomaculata (Storer)—Northern red-bellied snake. Johnson County: 2, 5. Generally uncommon.

Natrix erythrogaster neglecta Conant—Red-bellied water snake. Johnson County: 7, 23, 37. Locally common.

Natrix rhombifera rhombifera (Hallowell)—Diamond-backed water snake. Johnson County: 8, 30, 33, 39; Massac County: 49. Locally common.

Natrix sipedon pleuralis Cope—Midland water snake. Johnson County: 2, 18, 36. Locally fairly common.

Agkistrodon piscivorus leucostomus (Troost) Western cottonmouth. Johnson County: 11, 30, 47. Locally fairly common.

Agkistrodon contortrix mokeson (Daudin) Northern copperhead. Johnson County: 2, 27, 32, 39, 41, 43. Generally fairly common.

Crotalus horridus horridus Linnaeus—Timber rattlesnake. Johnson County: 42. Generally uncommon.

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TABLE I.—Herpetofauna Collecting Sites and Their Specific Locations, Southern Illinois.

Johnson County

1.	Nelson Spring	—T. 13S, R. 4E, SW¼ of Sec. 17.
2.	Little Stoney Bluff	—T. 13S, R. 3E, SE¼ of SW¼ of Sec.30.
3.	Prichard Farm	—T. 13S, R. 3E, NW¼ of SW¼ of Sec. 10.
4.	Belknap Road	—T. 13S, R. 3E, NW¼ of Sec. 33.
5.	Bird Spring	—T. 13S, R. 3E, SW¼ of SW¼ of Sec. 31.
6.	Begg Pond	—T. 13S, R. 2E, NE¼ of Sec. 7.
7.	White Hill Quarry	—T. 14S, R. 2E, SW¼ of Sec. 5.
8.	Dick Pond	—T. 14S, R. 2E, NE¼ of NE¼ of Sec. 12.
9.	Spout Spring	—T. 14S, R. 2E, SW¼ of NE¼ of Sec. 1.
10.	Sander Spring	—T. 13S, R. 3E, NE¼ of NW¼ of Sec. 21.
11.	Little Black Slough	—T. 13S, R. 2E, NE¼ of Sec. 35.
12.	Kaiser Farm	—T. 14S, R. 2E, NE¼ of NW¼ of Sec. 10.
13.	Case Bluff	—T. 13S, R. 3E, SW¼ of NE¼ of Sec. 21.
14.	Trovillion Spring	—T. 13S, R. 4E, NW¼ of NW¼ of Sec. 13.
15.	Sico Spring	—T. 13S, R. 3E, SW¼ of Sec. 15.
16.	Anderson Spring	—T. 13S, R. 3E, SW¼ of NW¼ of Sec. 10.
17.	Fitche Spring	—T. 13S, R. 4E, NW¼ of SE¼ of Sec. 27.
18.	Farm Pond.	—T. 13S, R. 2E, Sec. 18.
19.	Mathis Pond	—T. 13S, R. 3E, SE¼ of SW¼ of Sec. 32.
20.	Route 146	—T. 13S, R. 4E, SW¼ of Sec. 6.
21.	Gravel Road	—T. 13S, R. 3E, SE¼ of Sec. 10.
22.	Moffort Bluff	—T. 13S, R. 2E, NE¼ of SE¼ of Sec. 26.
23.	Paine Place	—T. 13S, R. 2E, NE¼ of Sec. 35.
24.	Morse Pond	—T. 14S, R. 2E, NE¼ of Sec. 2.
25.	Reevesville Cemetery	—T. 13S, R. 4E, NW¼ of SE¼ of Sec. 36.
26.	Mescher Spring	—T. 14S, R. 2E, NE¼ of Sec. 2.
27.	Belknap	—T. 14S, R. 2E, SW¼ of Sec. 1.
28.	Veach Hollow	—T. 13S, R. 3E, SW¼ of Sec. 14.
29.	Old Metropolis Road	—T. 13S, R. 3E, SW¼ of NW¼ of Sec. 10.
30.	Levee Slough	—T. 13S, R. 3E, SW¼ of NE¼ of Sec. 31.
31.	Wick Hill	—T. 13S, R. 2E, NE¼ of SE¼ of Sec. 26.
32.	Foreman Junction	—T. 13S, R. 3E, NE¼ of Sec. 31.
33.	Mulkey Pond	—T. 13S, R. 2E, NE¼ of SE¼ of Sec. 34.
34.	Pipe Spring	—T. 12S, R. 3E, NW¼ of Sec. 18.
35.	Dripping Spring	—T. 12S, R. 3E, NW¼ of Sec. 18.
36.	Prichard Farm	—T. 13S, R. 3E, SE¼ of Sec. 9.
37.	Marshall Pond	—T. 14S, R. 2E, SE¼ of Sec. 12.
38.	Heron Pond	—T. 13S, R. 3E, NW¼ of SW¼ of Sec. 30.
39.	High Banks	—T. 13S, R. 3E, NW¼ of SW¼ of Sec. 31.
40.	Merchant Farm	—T. 13S, R. 3E, NW¼ of Sec. 32.
41.	Main Bros.	—T. 13S, R. 3E, NE¼ of SE¼ of Sec. 30.
42.	Huckleberry Hollow	—T. 13S, R. 3E, NW¼ of Sec. 34.
43.	Route 45	—T. 13S, R. 3E, NW¼ of SE¼ of Sec. 28.
44.	Thorne Pond	—T. 13S, R. 3E, NW¼ of SW¼ of Sec. 31.
45.	Mason Cave	—T. 14S, R. 2E, NE¼ of Sec. 6.
46.	Belknap Road	—T. 14S, R. 3E, NW¼ of Sec. 6.
47.	Cypress Swamp	—T. 13S, R. 4E, NE¼ of Sec. 14.

Massac County

48.	Cagle Spring	—T. 14S, R. 4E, NE¼ of Sec. 10.
49.	Black Bottoms	—T. 16S, R. 6E, SE¼ of Sec. 23.
50.	Metropolis	—T. 16S, R. 4E, SW¼ of Sec. 2.
51.	Joppa	—T. 15S, R. 3E, SW¼ of Sec. 24.

Pope County

52. Jackson Hollow —T. 11S, R. 5E, S½ of Sec. 31.
53. Stafford Bluff —T. 13S, R. 5E, SW¼ of Sec. 29.

Pulaski County

54. Farm Pond —T. 14S, R. 2E, NE¼of Sec. 30.
55. Main Bros. Sawmill —T. 14S, R. 2E, NW¼ of SE¼ of Sec. 15.

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy and one carbon copy should be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. An abstract must accompany each article. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, *Acknowledgments*, and *Literature Cited*.

No footnotes are to be used in the text.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, J. H. 1951. The life cycle of a land snail. Conchol. 26(3): 21-32, 2 tables, 3 figs.
Doe, J. H. 1951. Mineralogy of Lower Tertiary deposits. McGraw-Hill Book Co., New York. iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908, p. 21) or (Doe, 1908, p. 21); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

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Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at the time galley proofs and manuscripts are returned to the Editor.

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PRESIDENTIAL ADDRESS

WHERE ARE WE HEADED?

HOWARD W. GOULD

Northern Illinois University, DeKalb

As I stand at the end of my teaching career of some 45 years, I feel that some personal opinions and general impressions of educational trends and problems in science teaching may be of more interest and value to the Academy than the description of a specific line of research. In view of curricular changes, the present overcrowding of schools, and the recognized importance of education in America, I doubt if there will ever be a more appropriate time to do this.

In the last decade, college enrollments have grown from about two millions to about 4.5 millions, with about seven millions predicted for 1970. This, of course, is due to population increase which reached a peak in accelerated growth about 18 years ago, also due to the fact that the proportion of high school graduates who enter college is increasing to a present value of about 60%. Most of this increase will be assumed by the public colleges and universities and junior colleges, rather than by the private schools who will continue to pick and limit their enrollments.

In America we have sought 12 years of education as being the right of everyone who is capable of it and wants it. Now public opinion tends to extend this to 14 years, or to include two years of additional training beyond high school. Professions which once called for high school diplomas now call for college training and specialization beyond. The limit to what the people want and will pay for remains yet to be seen.

Now science is involved in this growth, along with all the other disciplines, since it is now included in the educational curriculum as contributing to the culture and satisfactory life of the educated person. More recently when the Russians startled us with their first satellite, Sputnik, everyone suddenly became interested in comparing our educational system with that of the Soviets. The implication was that we should expect our children to learn more of everything, and more science in particular.

How much science do we require of all our students in American colleges? Well, a recent survey of 65 selected schools reveals that two to four semesters of science are usually prescribed under general education. Such requirements fall under two general choices: (1) selection of one or more laboratory courses in the sciences which are also taken by majors and minors, and (2) special abbreviated or cross-disciplinary sequences which are more or less integrated and terminal in treatment.

These courses are under continuous scrutiny and revision. With apology to the biological sciences, I shall indicate trends chiefly in the physical sciences with which I am identified by direct experience.

Chemistry and physics have been taught both separately and as combined physical science with and without inclusions of illustrative material from geology and astronomy. The emphasis has shifted from a survey of many topics to the selection of a few, then to a few basic principles with applications from selected elements and areas. In some cases, all the sciences and mathematics have been included in a more or less integrated sequence and presented by several instructors. My experience with such courses leads to the belief that a minimum of eight semester hours should be devoted to a physical science combination if a fair acquaintance with the area is to be attained. There is increasing favor toward such a sequence rather than abbreviated separate courses in chemistry and physics. But lack of interest or fear or loss of students by a single department explains the slow change.

The manner in which such courses are offered varies along the lines of lecture and laboratory sections, or lecture-demonstration and visual aids with optional laboratory or without it. More recently, closed-circuit television has been used for large numbers of students in different rooms. The success of this last innovation depends heavily on the care and skill with which the lecturer makes his presentations. The requirements are of a high order, comparable to those for a successful sound movie program, like the Baxter series in chemistry or the White series in physics. Attempts to measure the relative efficiency of different methods of presentation indicate that the method used is less significant than the skill of the instructor and his success as compared to that of other instructors.

I refer now to courses for physics and chemistry which are set up for majors and those in related fields. The content, scope, and treatment of these also have been undergoing change. In high school, the original intent was college preparation. Since most students then did not go on to college, more practical terminal courses were devised. And now, more recently, the prevalent idea is not to include any number of topics but to emphasize general properties, energy change, and atomic and molecular structure, as in the PSSC program in physics, and the CHEM study and the chemical bond approach (CBA) in chemistry. In college, introductory chemistry and physics likewise have been undergoing extensive change. General physics has comprised anywhere from one to two years of time, involving the use of varying amounts of calculus, with more time spent on atomic physics and less regard for covering all areas such as acoustics or fluids. General chemistry now emphasizes atomic structure and the nature of chemical bonding, energy and chemical equilibria, and colligative properties of solutions. The laboratory work includes more quantitative experiments and increased use of modern instrumentation. In short, it includes much material which once was confined to courses in physical

chemistry, quantitative analysis, and atomic physics. All this is by way of adjustment to what has been going on in high school chemistry and in advanced college courses.

Opportunity is now provided for high school graduates of exceptional ability or training to elect honor sections in college, or to by pass one or two semesters of introductory courses by proficiency examinations. Incidentally, college entrance requirements are gradually being raised in the public institutions as well as in private schools. So that those in the lower half or so of the high school diploma graduates must pass entrance tests to be eligible for admission. Reasonable standards of reading, writing, and speaking ability are more and more required for college entrance. The responsibility for correcting deficiencies in these respects is left to the elementary and secondary levels. There is also the fair certainty that more equal educational opportunity for minority groups will soon be effected, as for the Negro in the southern states, so that the success of these in college will be more likely. Post graduate high school work, trade schools, and junior colleges are already coming to be likely places for successful work immediately beyond high school graduation.

The increase in college enrollment calls for teachers to be trained for it. An earned Ph.D. is practically a prerequisite for upper rank college teaching. The number of institutions offering the Ph.D. has increased markedly in the last 40 years, and the number of degrees per year has increased from about 8000 in 1925 to about 25,000 now. The rate of increase in recent years is more sharply upward. Of this total, roughly about one-fifth are in the physical sciences. But, considering that many go into industrial research work, there are fewer available for college teaching positions — particularly in physics and mathematics.

May I now comment on a few aspects which I think need improvement. Ph.D.s in college teaching are frequently in an atmosphere where the emphasis is solely on scholarly research. This is particularly true in growing institutions where graduate programs are just getting under way. Promotions in salary and rank are too often based primarily on productive scholarship as evidenced by the number of publications. Those interested in teaching are in danger of being by-passed, no matter how good they are, unless they are also productive scholars to the extent of adding to the flood of routine and often mediocre scientific literature.

One of the principal functions, if not the chief one, of a university is teaching. By teaching, I mean any and all ways in which information is imparted. It is personally delivered by the staff in lecture, quiz, seminar, laboratory, and individual conference. In the mind of the student, any school is good or bad chiefly in terms of the atmosphere he experiences from his professors and staff in general. I do not mean to imply that more attention should be given to teaching at the expense of research. Actually the two are complimentary. Teaching is strengthened by research. And there is no substitute for thorough grounding in a discipline. It is just that any Ph.D. who expects to work in an

educational institution should include teaching assistantship work in his training program. Excellence in teaching should be rewarded on a par with excellence in technical research ability.

Relative to the teaching function in a growing institution, there is the pressure to keep down per capita cost of instruction in various ways. Among these devices are the giant-size lecture sections, and the use of as few quiz and problem sessions as possible and supervised by junior staff or graduate assistants. This means less personal contact between the student and the senior staff. This system, although not as ideal as that in a smaller school, is not too bad if the junior staff is competently supervised and coached in teaching procedure. A graduate assistant should not be compelled to choose between doing a good job at his research and preparing for his degree examinations on the one hand, and teaching and counselling his students on the other. All too frequently he cannot do both successfully. I am disturbed by the report at Northern that there is an increasing number of transfer students to and from other schools. One explanation for this, presumably, is an unfriendly or unsympathetic teaching atmosphere.

Members of the Academy have been concerned about the lack of science background of many high school science teachers, particularly those teaching chemistry and physics. Much progress has been made to correct this in Illinois in recent years, due to consolidation and to raised standards. I want to call attention here to elementary education. The State course calls for science throughout the elementary grades. But the extent to which a good science program can be implemented depends on the science backgrounds of the teachers. In my opinion, the elementary education major has too little opportunity to acquire an adequate science background in the usual elementary curriculum which is heavily loaded with professional courses. While I do not disparage methodology, I do insist that there is no substitute for grounding in an area, be it narrow or broad. A scholar with no grasp of how to deal with youngsters and how to put his subject matter across to them makes a poor teacher. But he is not so misleading and pathetic as one who knows all about how to teach but has nothing to teach. A reasonable balance of the two is in order. In Illinois, the responsibility for curriculum improvement centers primarily at schools of education in the State colleges. For the Office of the Superintendent of Public Instruction now accepts for teacher certification the curricula set up by the schools whose business it is to train teachers. Those trained elsewhere must satisfy the requirements set up by the State Office.

There is general concern about implementing curricular change. In smaller institutions, this is handled by faculty committees working with the dean or president. In larger ones, direct faculty participation becomes unwieldy, and it is difficult or impossible to arrive at any consensus. Consequently, the major portion of the task falls to general councils, senates, deans, and upper cabinets in a university hierarchy.

Vested interests and log-rolling tactics are omnipresent, which means that administrators must assume more and more responsibility for seeing to it that curricular and course development keep fairly consistent with expert and general opinion. This calls for well grounded disciplinary training and due regard for democratic procedure on the part of the administration.

Another problem relates to the facilities used in instruction. Rapid expansion calls for systematic long-time planning. Assuming that the necessary capital is forthcoming, about four years is needed to analyze needs, plan, design, construct, and to equip a major building and move into it. Frequent change of program calls for construction of inner partitions and layout of facilities to permit readaption to new uses at minimum expense.

In the matter of mass instruction in large sections referred to above, lecture demonstrations are more needed, particularly where individual laboratory work is optional or omitted entirely. There is usually a shortage of class and lecture room space on the campus, so most large lecture rooms where demonstrations are held are used by other classes most of the scheduled hours of the day and night. Facilities, therefore, must provide for the setting up of equipment and materials on portable desks which can shuttle back and forth between service and lecture. Visual aid equipment should be, so far as possible, readily operable by the instructor without the aid of assistants. "Foreign" instructors and students should not tamper with equipment left set up for use by another instructor. Each should be alert to the needs of others also using the room. All this is not easy, and far from ideal for the demonstrator. But his painstaking work adds immeasurably to the value of the course for the students. As I look back on my own training, I realize that some of the best instruction I experienced was due to well-organized and demonstrated lectures. The excellent work of Richard Sutton in physics and of Hubert Alyea in chemistry, along with that of many others, is noteworthy in this connection. May such as they not become extinct.

The testing program used in these mass education sections also has problems. Objective forms of tests have largely replaced those of the essay type, due to lack of time and staff. Certainly, one important factor in good instruction is the quality and dependability of the tests used. Much is needed for the construction of a standardized test which is fairly free from ambiguous statements. There is also the problem of minimizing opportunity for student cheating. Over all the testing there hangs the question, what am I trying to measure, and how well am I doing it?

These are some of the educational problems that I have been engaged in and which I think are significant and important. If I were just now starting in again, I am sure that I would find more and better challenges than I found 45 years ago. I believe that we are just really getting started in this business of learning.

Presented April 23, 1965.

ORGANS OF THE LARVAL AXOLOTL (*SIREDON MEXICANUM*) GROWN SINGLY OR IN COMBINATION *IN VITRO*

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ABSTRACT.—Organs of the larval axolotl were grown either singly or in various combinations in watch glass cultures for 21 days. Testis, mesonephros, brain, spleen, pancreas, heart, ovary and liver, when grown alone, were each well maintained except for the liver. Combinations of ovary and testis resulted in suppression of germinal cells of the ovary. Testes, when grown with mesonephros, showed lumina in some of the seminiferous tubules. Testes and other organs, when paired, were similar to the same organs grown alone. Ovaries, paired with mesonephros, spleen, or brain, had fewer degenerating ovocytes and proliferation of young germ cells and non-germinal elements. Ovarian tissue was destroyed by pancreas, and when paired with liver, neither organ was well maintained.

The *in vitro* cultivation of tissues and organs from cold-blooded vertebrates has been attempted by several investigators. Wilde (1950, 1955) and Wolf and his co-workers (1957, 1960) have maintained cells and tissues of fishes and amphibians. Foote and Foote (1958, 1959, 1961, 1962) have used a number of amphibian species to study the development of the reproductive system *in vitro*. The present paper is a report of efforts to cultivate tissues and organs from the axolotl (*Siredon mexicanum*), and to determine whether there is any beneficial result from growing two different organs together.

MATERIALS AND METHODS

Larval stages of the axolotl, 4 to 5 months of age, each with a total body length of 10-12 cm., were used. These larvae were placed for 24 hours in large finger bowls containing solutions of sulfadiazine and streptomycin in an attempt to make them bacteriologically sterile. To remove the organs for culturing, the animals were decapitated and pinned out in sterile wax-filled dissecting pans. Care was taken not to rupture the gut since the antibiotics were not ingested in observable amounts by the larvae. Organs were dissected, cut into small pieces for explanting into culture, and placed in Tyrode's solution diluted 2:1 with double distilled water. Culture methods employed were those of Wolff and Haffen (1952), modified for amphibian tissues. The culture medium was as follows:

Tyrode's solution (2:1)	3 parts
Chick embryo extract (EE50)	3 parts
Distilled water	4 parts
Agar-agar (1%)	5 parts
Penicillin & Mycostatin	

Those components were put into sterile embryologic watch glasses and allowed to solidify. The explants were then placed on the solid substrate, usually 5 or 6 explants arranged in a circular pattern for culture of single organ pieces. In the case of the "sandwich" preparations, the ovary was cut transversely into a number of sections and small pieces of other organs were placed inside the ovarial cavity before putting the combination on the medium.

The two organs were thus maintained in intimate contact during the culture period. Other preparations of pairs were placed side by side in contact on the culture medium. A cover glass was placed over the watch glass and sealed with melted paraffin, making sure the seal was airtight. Cultures were maintained at approximately 21-24 degrees C. Dishes were opened and explants transferred to fresh media each fifth day. After a culture period of 10 to 21 days, explants were removed from culture and fixed in Bouin's solution. They were then sectioned by the paraffin method and stained in hematoxylin and eosin.

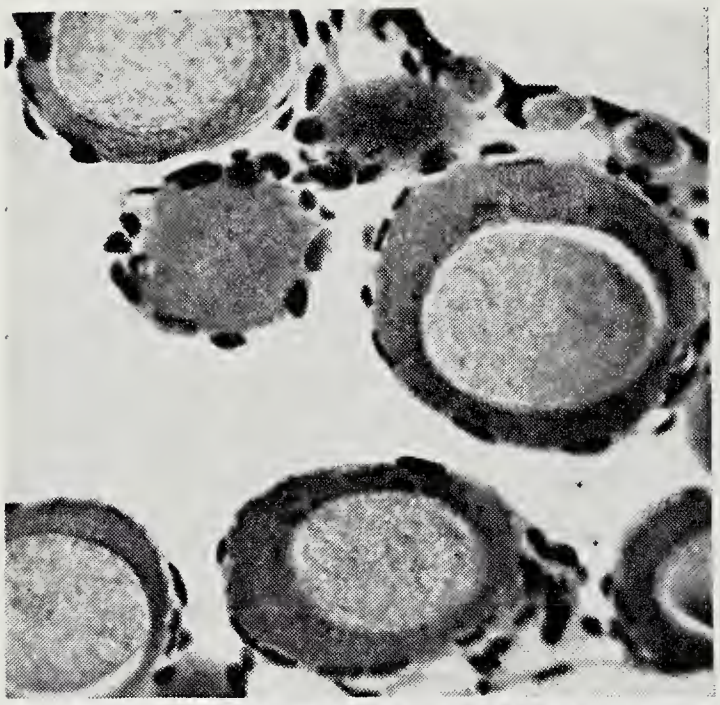
Organs placed in culture were testes, ovaries, heart, liver, mesonephros, pancreas, spleen and brain and combinations of these in pairs. Table 1 shows the number of explants and the time in culture.

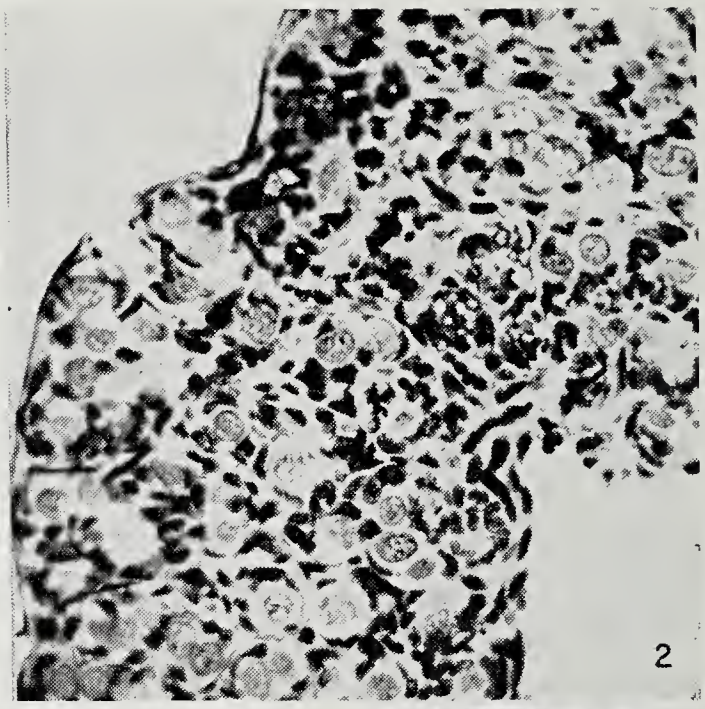
Results from Tissues Grown Alone in Culture

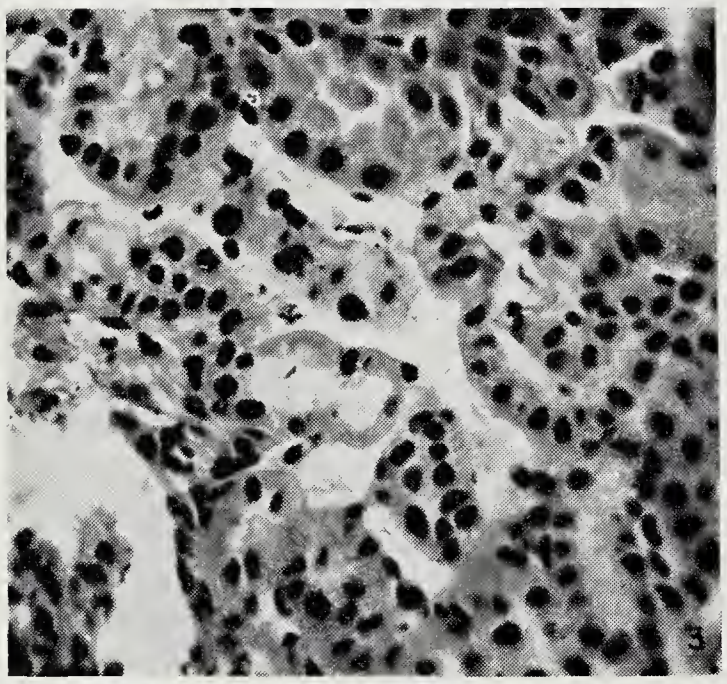
Testis-Control. The general appearance of the control testis is that of very closely packed cells with no spaces except for an occasional blood vessel. The beginning of the formation of seminiferous tubules is indicated by the fact that the germ cells occur in groups of 2 or 3, surrounded by follicle cells, but with no apparent lumina. The germ cells are in pre-miotic stages (spermatogonia or primary spermatoctyes); their nuclei are spherical, unlobulated, and they stain less darkly than those of the follicle cells. The cytoplasm of the germ cells is clear. Explants were taken from both the center and periphery of the gonad and as a result some do not have any part of the tunica albuginia.

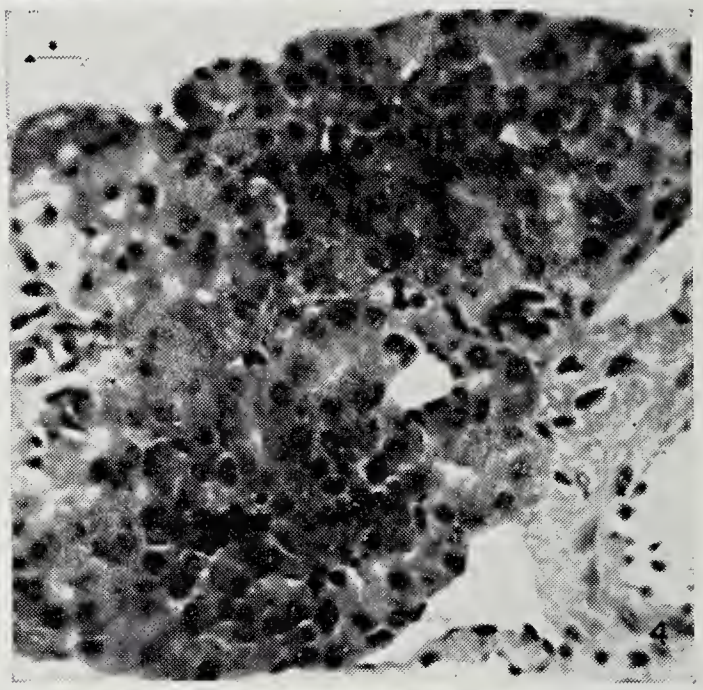
Testis-Cultured. In explants cultured for only 3 to 4 days, the germ cells and seminiferous tubules show no marked changes from controls. There is a somewhat less compact appearance due to a looser arrangement of non-germinal elements. After 10 days in culture a continued proliferation of non-germinal elements takes place, resulting in a less compact appearance. Germ cells remain as in the controls, except that lumina appear in a few of the seminiferous tubules. After 21 days in culture the non-germinal cells have increased greatly in number and may make up as much as half of the explant. The germ cells are fairly well maintained, but the demarcation between nucleus and cytoplasm is less distinct and the chromatin stains less densely than in the controls (Pl. I, UR).

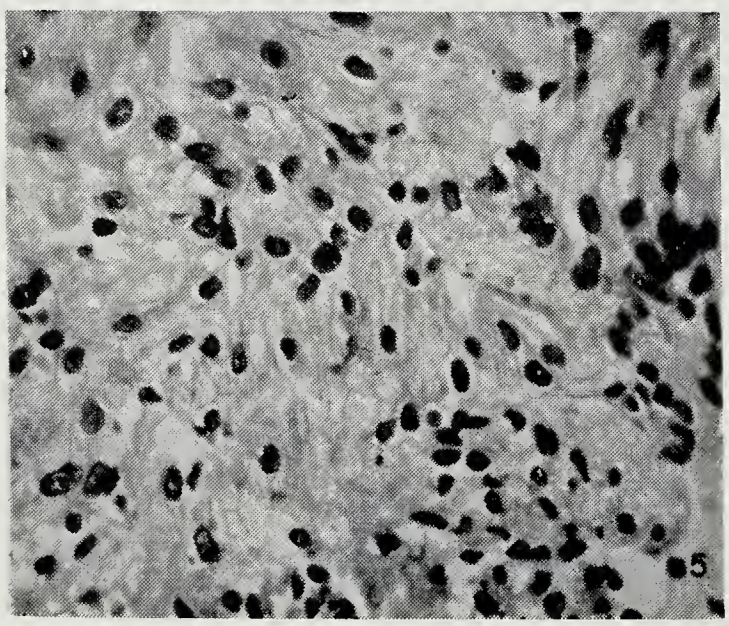
Ovary-Control. The cortex of the ovary is somewhat less compact than the testis. It is surrounded by the theca externa. There is a large ovarial cavity. At the periphery of the ovary there are nests of 5 or 6 gonial cells with large lobulated nuclei and with very little cytoplasm. At this stage of development the greater part of the cortex is composed of auxocytes, i.e. oocytes with little deposition of yolk. Their nuclei are large and spherical, containing many nucleoli, but with no indication of chromosomes. The auxocytes have few follicle cells apparent and are supported primarily by the cells of the theca interna. Ovarial explants were cut in such a way that each piece had a portion of the theca externa on one side.











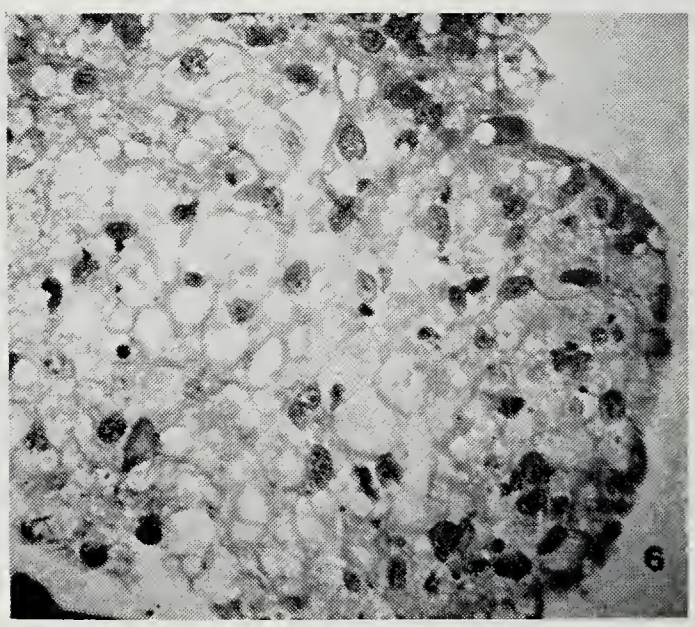


PLATE I.—Sections of organs of axolotl, grown alone in culture for 21 days. x200. Upper left (UL), ovary; upper right (UR), testis; middle left (ML), mesonephros; middle right (MR), pancreas; lower left (LL), heart; and lower right (LR), liver.

Ovary-Cultured. Ovaries in culture for 21 days show the same general structure and types of cells as do the controls (Pl. I, UL). There is some indication of degeneration of cells, especially large ovocytes, but there are no large necrotic areas. Auxocytes have large nuclei showing dark staining chromatin. Oogonia appear to be in good condition and are located near the periphery of the explant. They have lobed nuclei and distinct cytoplasm. The main change from the controls appears to be in the non-germinal cells. These have proliferated somewhat from some areas of the explant and appear to have originated from stromal and thecal cells. Some sections of the ovary show groups of cells arranged near the periphery in such a manner as to form "bubbles." Many explants showed these "bubbles" while they were still in culture. In some explants the thecal membranes are very distinct and the auxocytes seem to have shrunken, making the cells of the thecal layers more conspicuous.

Heart-Control. The cardiac muscle fibers are distinct but show no striations in these preparations. Fibers form distinct bundles which lie in different planes and run in various directions. Anastomosing bundles can be observed. There are many nuclei of essentially ovoid form which stain darkly. An occasional mitotic figure is seen.

Heart-Cultured. Explants of heart continue to beat while in culture. Most explants show pulsation up to ten days, but after that time there is a decrease in movement. In stained and sectioned material the fibers and nuclei do not look too healthy, even in those explants which showed contractions during the culture period. In these explants there are always outgrowths of cells. These do not proliferate as individual cells, but extend away from the explant as more or less solid sheets of cells. The area of outgrowth has the same form as the heart muscle itself, but always stains with a basic stain whereas the main body of the explant stains with acid stain. It appears that the typical cytoplasm of the muscle fiber has not yet differentiated in the outgrowth from the explant. The heart explants seem to be somewhat reduced in size after being in culture for 21 days and the fibers are more closely massed together (Pl. I, LL).

Liver-Control. The liver is a reticular gland composed of many cells which in cross-section have 3, 4 or 5 sides. While the cells are roughly square in outline, they are very irregular and vary considerably in size. The liver is not divided into lobes, as it is in man and higher vertebrates. Each cell has a rounded nucleus surrounded by a large area of cytoplasm which contains dark staining granules. The outline of each cell is very distinct due to the dark staining reaction of the material between the cells. The outermost cells of the liver are closely packed and have very little cytoplasm and relatively large nuclei; in this area the cytoplasm and cellular outline, are not distinct due to the multitude of nuclei. There are occasional mitotic figures. Pigment cells and large blood and lymph vessels are interspersed in the tissues of the liver.

Liver-Cultured. The most marked

change in liver explants following a period in culture is a decrease in size of the explant. This is due for the most part to the loss of individual cells from the periphery of the explant while it is in culture. Apparently the cells do not adhere well to each other and a capsule around the explant is not formed. After 10 days of cultivation, cells retain their irregular form, each with a distinct nucleus, but the cytoplasm becomes filled with small vacuoles. After 21 days in culture, the cytoplasmic vacuoles have increased in size so that the explants have the appearance of a reticulum with numerous nuclei, many of which seem to be necrotic (Pl. I, LR).

Mesonephros-Control. The kidneys are elongated and composed of mesoneprhic tubules with few glomeruli and large Bowman's capsules. The tubules vary in size as does the height of the epithelium in each tubule. Each cell has a distinct ovoid shaped nucleus. Some pigment cells are present especially in the areas of the blood vessels. In some sections the Mullerian and Wolffian ducts are present.

Mesonephros-Cultured. Mesonephric kidneys maintained in culture as long as 21 days show no marked changes from control organs (Pl. I, ML). The tubules remain distinct with no apparent changes in cell form or structure. There are some tubules which are distended, due apparently to accumulated fluids. Some tubules contain material which may have been secreted from the cells or perhaps taken from the medium through the nephrostomes. The gonaducts seem to be well maintained in culture and retain their normal appearance.

Pancreas-Control. This organ has a lobulated appearance, but it is compact and individual alveoli are not distinct. The cell form varies from cuboidal to columnar. The nuclei are large and rounded and centro-acinar cells are present. Many cells have secretory granules in the apical parts of the cells. The islet cells can be identified.

Pancreas-Cultured. This organ seems to be in very good condition after 3 weeks in culture. In some areas of the explant the alveoli are much more distinct than they are in the controls. This may be due to a separation of one alveolus from another after the organs were dissected for explants or it may possibly be due to a loss of connective tissue while the organs were in culture. Some explants look as compact as in the control material (Pl. I, MR) Secretory granules are very conspicuous in pancreatic cells, but less abundant than in the controls. Some islet cells are present.

Spleen-Control. The spleen is a rounded organ, surrounded by a connective tissue capsule. There are no trabeculae, nor are there definite groups of white cells as seen in the spleen of higher vertebrates. Leukocytes and erythrocytes seem to be distributed throughout the organ, in about equal numbers. Mitotic figures are very common. The reticular cells are large and form a supporting network for the blood cells.

Spleen-Cultured. The form of the spleen is very similar to that control, and the explants show little decrease in size. The number of

leukocytes is approximately equal to that of the controls, but few erythrocytes remain in the explants. The reticulum is much more distinct after culturing and the reticulum makes up more than half the bulk of the explant. Some mitotic figures were observed in cultured material.

Brain-Control. The part of the brain used in this study was the diencephalon. Areas of grey and white matter are very distinct. The grey matter, nearer the brain cavity, contains at least two distinct types of nerve cells, whereas the white matter is composed primarily of fibers and supporting tissues. In some sections the choroid plexus is present.

Brain-Cultured. Cultured explants show the same general plan as controls, with distinct areas of grey and white matter. In the grey matter the two types of nerve cells can be identified easily. A few vacuoles have formed in the supporting tissue of the grey matter and some of the nerve cells are more clumped together. The nerve cells of the explants, however, seem to be in excellent condition. Some mitotic figures were observed in the grey matter.

Results from Tissues Grown in Combinations in Culture

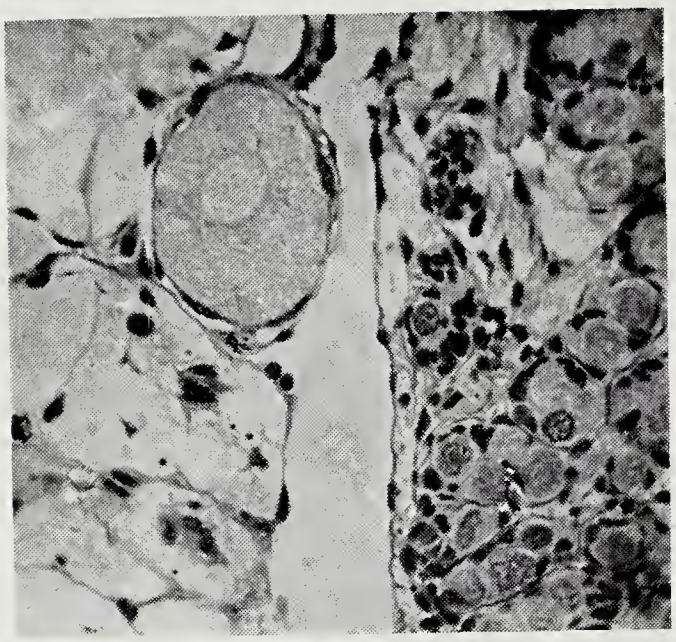
Testis and Ovary-Cultured. Explants of both testis and ovary have a very loose structure and give the appearance of a network of connective tissue supporting the germ cells. There has been some proliferation of non-germinal cells from both organs and these have grown in contact with each other. Whereas the germ cells of the testis look essentially normal, the explants of the ovary contain few germ cells, auxocytes or oogonia. Only about 10% of the usual number of ovarial germ cells remain in the explants (Pl. II, UL).

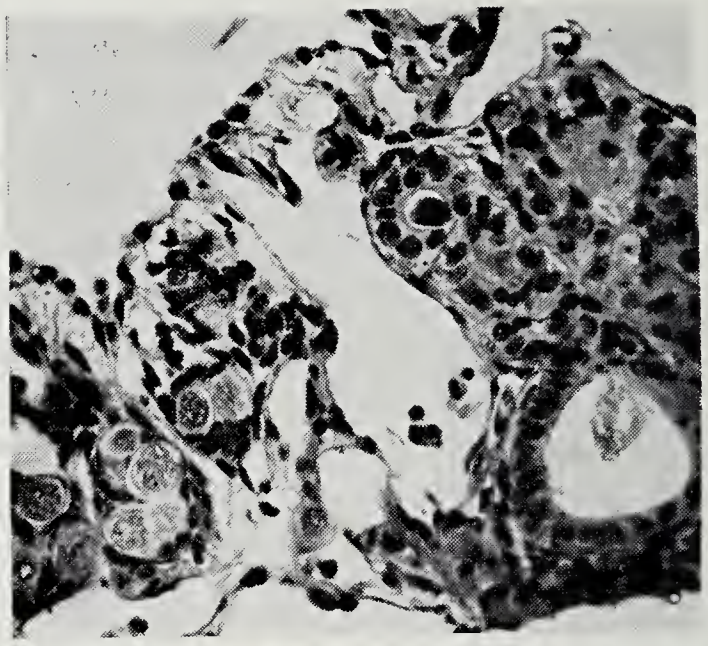
Testis and Heart-Cultured. Explants of testis and heart are grown together and cells from the heart have invaded the gonad. Neither organ, however, appears to be in good condition. The explants of the testis lack the characteristic organization and few germ cells are present. Fibers of cardiac muscle are distinct, but no striations are visible.

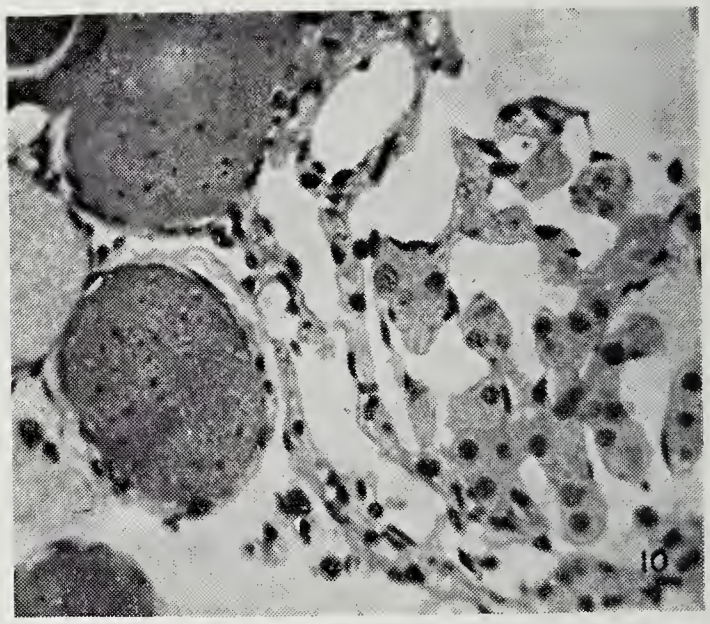
Testis and Liver-Cultured. Explants of testis and liver are very closely attached. Germ cells of the testis look healthy with normal appearing follicle cells. The testis is very compact. More connective tissue is present in the testis and the testis portion of the explant is encapsulated, whereas the liver portion is not. Liver explants appear very similar to those cultured alone, with loss of typical cell structure and organization.

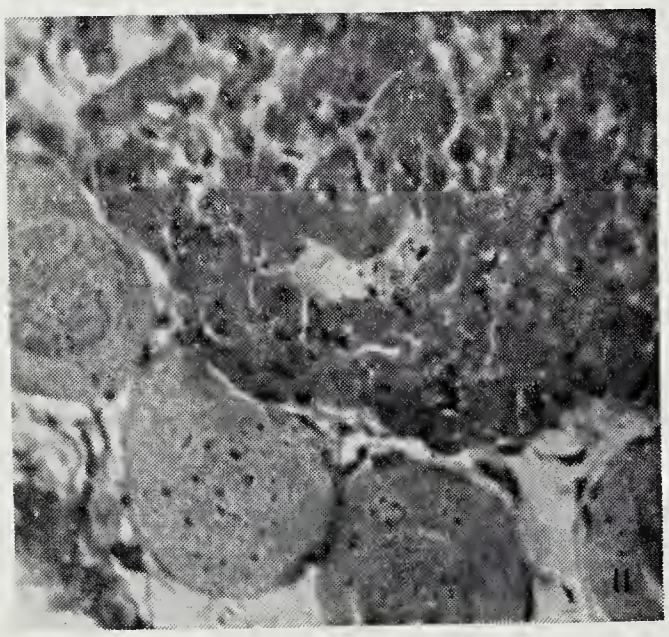
Testis and Mesonephros-Cultured. Testis in combination with mesonephros looks essentially normal (Pl. II, UR). Explants are compact and with less connective tissue between the seminiferous tubules than when grown with liver. In some instances the cells from the mesonephric tubules have intermingled with the germ cells of the testis. In some explants of mesonephros grown with testis, the Wolffian ducts appear to be more dilated than those of kidney grown alone.

Testis and Pancreas-Cultured. The pattern of testis and pancreas grown together differs from that of









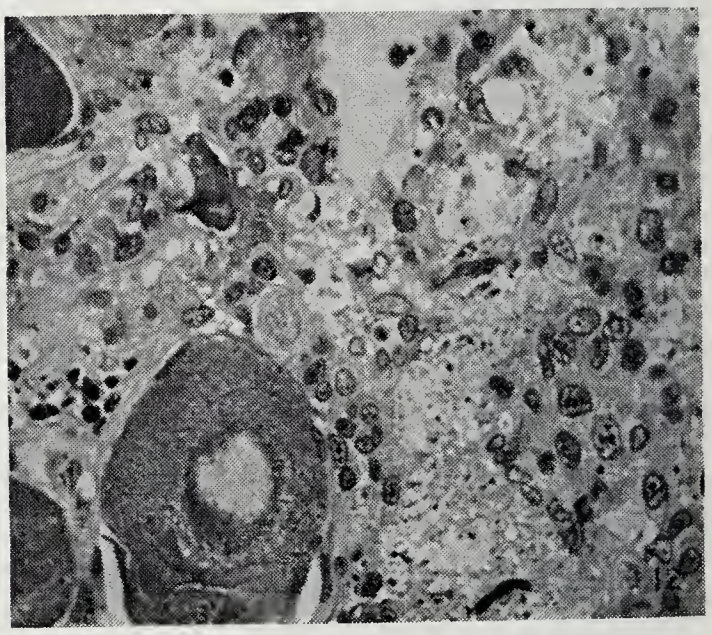


PLATE II.—Sections of organs of axolotl, grown in pairs in culture for 21 days. x200. UL, ovary and testis; UR, testis and mesonephros; ML, ovary and mesonephros; MR, ovary and pancreas; LL, ovary and heart; and LR, ovary and liver.

the testis and liver and of the testis and mesonephros combinations. The tissue of the testis is much less compact, but there are spaces between the seminiferous tubules. Such areas in explants of testis grown alone con-

tain connective tissue. The germ cells are as well maintained as when testis is cultured alone. The pancreas explants look healthy with distinct alveoli. Some cells from the pancreas explants have grown around the testis explants to form a capsule.

Ovary and Heart-Cultured. In this combination there is an intermingling of cells from the two organs whether they are placed side by side or whether the heart explant is inserted into the ovarial cavity. The heart appears characteristic for cultured material. The ovaries as well maintained with only a few degenerating auxocytes. There is little proliferation of non-germinal cells (Pl. II, LL).

Ovary and Liver-Cultured. These explants were placed side by side or explants of liver were inserted into the ovarial cavity. Neither explant appeared to be in good condition (Pl. II, LR). The ovary showed many degenerating auxocytes, although some younger germ cells were present. The non-germinal cells had proliferated extensively. In some cases, where the cells of the liver were in close contact with the ovary, these cells appeared to be better maintained than were liver cells alone.

Ovary and Mesonephros-Cultured. There are very few degenerating auxocytes in ovaries in combinations with mesonephros, and the ovaries look very much like uncultured controls (Pl. II, ML). The explants of mesonephros show distinct tubules, occasional glomeruli, and Wolffian and Mullerian ducts. Some tubules, as well as the Wolffian and Mullerian ducts, may be dilated. In some combinations the cells of the kidney explants surround the auxocytes. In instances where kidney explants are placed in the ovarial cavities, these cavities are much distended and germ cells are located in a thin band surrounding the cavity and kidney explant.

Ovary and Pancreas-Cultured. Pancreas explants look healthy and similar to explants grown alone. However the ovarian explants have been almost totally destroyed, apparently by enzymes from the pancreas. Many partially degenerated auxocytes are surrounded by cells from the pancreas. A few oogonia and oocytes can be identified (Pl. II, MR).

Ovary and Spleen-Cultured. The ovary appears to be in good condition and all types of cells can be identified. The reticular cells of the spleen have in some instances invaded the ovary and surrounded the germ cells, resulting in some degeneration of auxocytes. The white blood cells of the spleen appear to be in excellent condition and some are undergoing mitoses. Red cells are present, but often are irregular in form.

Ovary and Brain-Cultured. Both explants of ovary and diencephalon appear healthy. In some instances the ovary has a few degenerating auxocytes, but younger germ cells are present. There has been some proliferation of non-germinal cells. The brain tissue is the more actively growing one; it has invaded the ovarian explants. Many fibers have proliferated from brain to ovary, especially where the brain was inserted into the ovarial cavity.

Discussion

The maintenance *in vitro* of embryonic cells and tissues of amphibians is a routine procedure in many laboratories. The cultivation of organs from larvae or adults is less frequently and less successfully accomplished. No comparative study of the survival in culture of different organs of a single species of amphibians exists. Neither has the possible effect of one organ on another *in vitro* been investigated in amphibians as it has been in some birds and mammals.

Wolff (1954) has demonstrated that different organs of one species of bird or mammal will grow together with the connective tissue elements often becoming indistinguishably intermingled. The more specialized tissues, such as epithelium of the bronchi or bronchioles, maintain their independence. Similar results were obtained with the culture of combinations of organs of different vertebrate classes, chick or duck and mouse, for example (Wolff, 1954; Wolff & Weniger, 1954; Salzgeber, 1962).

Wolff and Wolff (1961, 1962) succeeded in growing cancer tissue, taken directly from a human patient, in association with chick mesonephros. These cancer tissues were maintained for 36-45 days, through several transfers, and continued to manifest the pattern associated with the particular type of original malignancy. Such organized tumors will not survive alone on the medium, although cell lines of malignant cells have been maintained for years.

There have been attempts to determine which factors from one organ in culture stimulate another organ. Lutz-Ostertag and Fargeix (1962) found that embryo chick Mullerian duct grew better in the presence of chick heart, and that the production of certain amino acids by the heart tissue enriched the medium. This was in accord with result of Pasieka et al. (1956), concerning the amino acid metabolism of cultivated chick heart fibroblasts.

Croisille (1958) used extracts of various embryonic chick organs as substitutes for complete embryo extract in the medium and found that liver extract and heart extract produced poor survival of the organs cultured. However, he obtained satisfactory results with extracts of mesonephros, lung, skin and intestine.

The present experiments indicate that in amphibian organs there is an advantage, in some instances, to growing organs in combinations. It was of particular interest to find some method of culture which would maintain the ovaries for long periods of time, permitting the various types of cells to differentiate. The hollow structure of the ovary presented an excellent situation for testing any stimulating effect which might be exerted by an associated organ. Ovaries in combination with mesonephros, heart, spleen, and brain appeared to be well maintained, with fewer degenerating cells than when grown alone. Mesonephros was the most satisfactory of the above organs. Neither pancreas nor liver promoted growth of the ovary in combination with it. The digestive enzymes of the pancreas may have destroyed the ovarian tissue. The liver has not proved to be an organ which is well

maintained in culture itself (see below). It has no apparent effect on the ovary. In the ovary-testis combinations the testis remains healthy but many of the ovarian germ cells degenerate. This may be considered an illustration of the free-martin effect.

The amphibian liver grows less satisfactorily in culture than does the liver of chick (Wolff, 1954) or mouse (Salzgeber, 1962). The cells become vacuolated and after 21 days in culture many of the cell membranes have disappeared, leaving a syncytial arrangement of both pycnotic and fairly normal looking nuclei. The organ fragment is difficult to handle, breaking into pieces when transferred to fresh medium or during preparation for histological study. Many cells slough off from the surface, giving the explant a ragged appearance. No surrounding membrane forms, although if the explant contains a portion of the serosa, that side of the explant will have a surface membrane. The serosa is not extended to the other surfaces of the explant. Since containment within some sort of membrane is essential for growth as an organ, this may be the explanation of the poor results with amphibian liver. The only instance in this experiment in which a piece of liver was in fairly good condition was one which was grown inside the ovarial cavity. It might be that the tissue of the ovary served as a membrane. It would be of interest to use the vitelline membrane technique (Wolff, 1960) with this organ to learn whether it could be well maintained if the membrane were provided for it.

The question of why mesonephros provides a more satisfactory situation for growth of the ovary than do the other organs tested cannot be answered on the basis of the present experiments. It might be explained either through the physical structure of the organ or its chemical activity. For human cancers, at least, the results from the separation of the cancer tissue from the mesonephros by a fold of vitelline membrane would seem to indicate that the effective factor is primarily chemical (Wolff and Wolff, 1961b).

The age of the organs or tissues used has a direct bearing on the results obtained. Explants from embryonic stages of amphibians readily grow and differentiate in culture. Larval organs grow, but continued differentiation of specialized cells, such as germ cells, is more difficult to obtain. Adult organ fragments are maintained with little change for some time, but ultimately there is cellular degeneration. Similar results have been reported by Steinberger et al. (1964) for growth of testicular tissue from rats of various ages.

Summary

Organs of the larval axolotl were grown either singly or in various combinations in watch glass cultures according to the method of Wolff and Haffen. They were maintained for 21 days. The organs cultured were ovary, testis, mesonephros, heart, liver, pancreas, spleen, brain, and pairs of ovary and testis with each of the others.

When organs are grown alone there is good maintenance of all organs except the liver. They might

TABLE 1.—Number of explants and time in culture.

Organ	Single cultures	Pairs-side by side	Pairs "sandwich"	Days in culture
Testis	4			4
"	18			10
"	5			21
Ovary	30			21
Heart	9			4-7
"	38			10
"	10			21
Liver	5			3-4
"	34			10
"	10			21
Mesonephros	11			10
"	10			21
Pancreas	9			21
Spleen	5			21
Brain	4			21
Testis & ovary		6		21
" " heart		6		21
" " liver		6		21
" " mesonephros		6		21
" " pancreas		6		21
Ovary & heart		5	10	21
" " liver		11	7	21
" " mesonephros		16	4	21
" " pancreas		12	4	21
" " spleen		11	5	21
" " brain		5	5	21

be arranged in a series of decreasing competence in culture: testis, mesonephros, brain, spleen, pancreas, heart, ovary, liver. In some of these there is little difference between two mentioned in sequence as to the quality of their response to the culture situation.

Ovary-testis pairs in culture result in suppression of the germinal cells of the ovary.

Combinations of testis with liver, mesonephros, or pancreas show little change in either organ of the pair from its condition when cultured alone. Some of the testes had lumina in a few seminiferous tubules when grown with mesonephros. In the testis-heart pairs neither organ appears to be quite as well maintained as each had been alone.

Combinations of ovary with mesonephros, brain and spleen are better maintained in pairs. There are few degenerating ovocytes; young germ cells and non-germinal elements have proliferated. In combination with heart, the ovary does not show any improvement over culture alone. Ovarian tissue is destroyed when in combination with pancreas, in contrast to the condition of testis-pancreas pairs. Neither ovary nor liver are well maintained when these two organs are paired in culture.

ACKNOWLEDGEMENT

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OXIDATION OF SUCCINATE BY BLUEGILL LIVER MITOCHONDRIA

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ABSTRACT.—(1) The succinic oxidase system of bluegill (*Lepomis macrochirus*) liver mitochondria was investigated. (2) Neither oxygen nor phosphate uptake was metal-ion dependent, but magnesium and ferric ions increased oxygen uptake. (3) Zinc and cadmium ions inhibited oxygen uptake. (4) Dicoumarol, gramicidin, 2,4-dinitrophenol, and pentachlorophenol uncoupled phosphorylation from succinate oxidation but also inhibited oxygen uptake. (5) Antimycin A, sodium azide, and sodium cyanide inhibited oxygen uptake.

Oxidative metabolism of the bioenergetic systems of fishes has not been extensively investigated until recently. The reviews by McCay (1957), Gumbmann et al. (1958), and Tarr (1958) cited only one report of oxidative systems in fish up to that time. Since Tarr's review, several additional reports have appeared: Ekberg (1958) considered energy metabolism in goldfish tissues. Brown and Tappel (1959) reported on fatty acid oxidation, and Brown (1960) discussed glucose oxidation by carp liver mitochondria. Kanungo and Prosser (1959) investigated the role of oxidative phosphorylation in cold adaptation in goldfish, and Gumbmann and Tappel (1962) studied the tricarboxylic acid cycle in carp liver mitochondria.

The energy-producing systems of the bluegill (*Lepomis macrochirus*) liver mitochondria were selected for study as one means of exploring the effects of pollutants on aquatic organisms. Although fish are poikilotherms and live in environments having restricted oxygen, they must produce energy via oxidative pathways. A preliminary report (Hiltibran 1964) indicated from oxygen uptake data that bluegill liver homogenates and mitochondria could oxidize various substrates of the tricarboxylic acid cycle. On the basis of these data, an investigation of oxidative phosphorylation with succinate as substrate was undertaken.

MATERIALS AND METHODS

Native, wild bluegills obtained from various bodies of water in central Illinois were maintained in aerated laboratory aquaria at 25°C. Preparation of the mitochondria and procedures for estimating oxygen and phosphate uptake have previously been reported (Hiltibran and Johnson 1965). Oxygen data were converted to $\mu 10_2$ per hour per mg of tissue nitrogen, and changes in the phosphate content of the reaction medium were converted to micromoles of phosphate per hour per mg of tissue nitrogen. All values were corrected for endogenous enzyme activity. The data presented are the average values from two or more experiments.

RESULTS AND DISCUSSION

Effect of homogenizing medium and time of centrifugation: The mitochondria for percursory experiments were obtained from homo-

TABLE 1.—The effect of homogenizing medium on O_2 and PO_4 uptake.

Medium	$\mu l O_2$/hr/mgN	μmoles PO_4/hr/mgN
0.25 M sucrose	123[a]	20
	65[b]	6
0.15 M sucrose	157[a]	32
	114[b]	20
	122[c]	20
	100[d]	(—) 24
0.08 M sucrose	175[c]	19
	152[e]	22
0.04 M sucrose	88	(+) 18
Water	66	(+) 20

[a] Tissue divided between 0.25 and 0.15 M sucrose.
[b] Second experiment between 0.25 and 0.15 M sucrose.
[c] Tissue divided between 0.15 and 0.08 M sucrose.
[d] Average of 10 experiments (0.15 M sucrose).
[e] Average of 13 experiments (0.08 M sucrose).
(+) Denotes increase of inorganic phosphate in reaction medium.

genates prepared in 0.25 M sucrose by centrifuging in a Servall refrigerated centrifuge for 20 minutes at 21,000 x g after preliminary centrifugation for 10 minutes at 800 x g (Schneider and Hogeboom 1950). Very loosely-packed mitochondrial pellets were obtained, whose oxygen uptake was variable. Since the results indicated that the conditions might not have been suitable for the preparation of bluegill liver mitochondria, an investigation was undertaken to determine the effects of centrifugation time and homogenization in various media on mitochondria.

The full oxidative potential of the homogenates was obtained by centrifugating the homogenates for 10 minutes at 21,000 x g after a preliminary centrifugation for 5 minutes at 800 x g to remove cellular debris.

The oxygen and phosphate uptake by mitochondria prepared in various sucrose media are summarized in Table 1. The results indicated that either 0.08 or 0.15 M sucrose was a better homogenizing medium than was 0.25 M sucrose. The mitochondria prepared in 0.15 M sucrose appeared to have greater phosphorylation efficiency and the mitochondria prepared in 0.08 M sucrose utilized more oxygen.

Since the full oxidative potential could be obtained by shorter periods of centrifugation and since the mitochondria prepared in 0.15 M sucrose utilized more phosphate, the mitochondria for the experiments reported here were prepared in pH 7.5 phosphate-buffered 0.15 M sucrose and were obtained from homogenates by centrifugation for 10 minutes at 21,000 x g following preliminary centrifugation for 5 minutes at 800 x g. The mitochondria were resuspended in the homogenizing medium, recentrifuged, and resuspended in the original volume of buffered sucrose.

Most investigators have used mitochondria in 0.25 M sucrose prepared according to Schneider and Hogeboom (1950). Brown and Tappel (1959) used carp liver mitochon-

dria prepared in fortified 0.20 M sucrose for the investigation of fatty acid oxidation. Gumbmann and Tappel (1962) used mitochondria obtained by 10 minutes of centrifugation at 11,000 x g. These data suggest that in fishes 0.25 M sucrose or prolonged centrifugation may not be desirable for the preparation of mitochondria or other cellular components.

Effect of cofactors: Oxygen uptake was drastically reduced in the absence of adenosinetriphosphate (ATP) and as much as 80 per cent of the oxygen uptake shown in the presence of ATP was restored by adenosinediphosphate (ADP). Coenzyme A (Co A) or ADP added to ATP did not appreciably alter either oxygen or phosphate uptake. Co A and ADP without ATP did not restore the oxygen uptake level above that shown by ADP alone. For maximum uptake of oxygen in the presence of succinate, ATP was required by the bluegill liver mitochondrial systems.

Bluegill liver mitochondria exhibited coupled oxidation and phosphorylation in the absence of a phosphate trap, but the conversion of inorganic phosphate into organic phosphate was increased by the presence of the glucose-hexokinase phosphate trap. Associated with the increased utilization of phosphate was a slight increase in oxygen utilization. Glucose alone was without effect on either oxygen or phosphate uptake. The oxygen uptake by unwashed mitochondria was increased by bovine serum albumin, but washed mitochondria did not exhibit this requirement. Cytochrome C added to the reaction medium resulted in a 30 per cent increase in oxygen utilization, presumably by increased electron transport. The above data indicate that ATP, cytochrome C, and the glucose-hexokinase trap are required for maximal oxygen and phosphate uptake.

Since electrons from succinate are not transferred to the cytochrome chain by diphosphopyridine nucleotide (DPN), the presence of DPN in the reaction medium would not be expected to have caused any effect. However, in all experiments in which DPN was addd to the reaction medium, oxygen uptake was substantially reduced. Triphosphopyridine nucleotide (TPN), on the other hand, did not have any effect on the oxidation of succinate. Thirty micromoles of succinate gave maximum oxygen uptake.

The effect of pH on the oxygen and phosphate uptake was limited to the effective range (pH 7 to 9) of Trishydroxyaminomethane (Tris) buffer. A broad range of activity was found from pH 7.2 to 7.8, and the oxygen and phosphate uptake activity decreased above and below those pH values. All subsequent analyses were determined at pH 7.5.

Effect of metal ions: The effects of several metal ions on the oxygen and phosphate uptake are summarized in Table 2. Oxygen and phosphate uptake occurred in the absence of any added metal ion, indicating that neither oxygen nor phosphate uptake was dependent upon the presence of ions. In the following experiments, the effects of the presence of metal ions were estimated.

Ten micromoles of the divalent magnesium ion and five micromoles

TABLE 2.—Effect of metal ions on oxygen and phosphate uptake.

Metal	μmoles added	$\mu 10_2$/hr/mgN	μmoles PO_4/hr/mgN
Control	none	76	(—) 12
Mg	10	125	(—) 20
Ferric	5	131	(—) 11
Manganese	5	29	(+) 22
Calcium	5	22	(+) 34
Zinc	1	.....	(+) 30
Cadmium	1	.....	(+) 41

of the trivalent ferric ion increased oxygen uptake. Magnesium ions, but not ferric ions, increased the conversion of inorganic to organic phosphate. The ratio of phosphate to oxygen utilized in the presence of the magnesium ions was approximately the same as the ratio in the control vessels. These observations suggest that since magnesium ions are necessary for maximal conversion of inorganic phosphate to tissue organic phosphate, the effect on oxygen uptake is indirect and due primarily to the increase in phosphorylation promoted by magnesium ions. Low levels of ferric ions increased the oxygen uptake but did not alter the phosphate uptake even though there was additional substrate oxidized and presumably additional energy available for phosphate conversion. The energy was apparently not utilized. Whereas 10 micromoles or more of ferric ions inhibited oxygen uptake, magnesium ion levels up to 30 micromoles did not further alter either the oxygen or phosphate uptake.

Effect of inhibitors: The effects of various enzyme inhibitors on the oxidation of succinate are summarized in Table 3. Antimycin A and sodium cyanide completely inhibited

TABLE 3.—Effect of inhibitors on oxygen and phosphate uptake.

Inhibitor	Amt/ml of reaction med. (μmole)	Ave. change in $\mu 10_2$/hr/mgN	Ave. change in μmoles PO_4/hr/mgN
Azide	1.7	(—) 95	(+) 10
Antimycin A	0.6	(—) 138	(+) 19
Cyanide	1.7	(—) 158	(+) 14
Fluoride	1.7	(±) 37	(±) 3
Malonate	1.0	(—) 108	(+) 1
Arsenate	1.7	(±) 27	(+) 29
Arsenite	1.7	(±) 26	(+) 9
Pentachlorophenol	0.017	(—) 96	(+) 45
DNP	0.1	(—) 150	(+) 46
Gramicidin	0.5[a]	(—) 102	(+) 14
Dicoumarol	0.017	(—) 35	(+) 15

[a] Micrograms.

oxygen uptake. The level of antimycin A used (0.033 μg per ml of reaction medium) was less than that reported by Kanungo and Prosser (1959) for the inhibition of oxygen uptake by goldfish liver mitochondria. Sodium azide was less inhibitory to oxygen uptake.

The effect of several oxidative phosphorylation uncouplers was investigated. Sodium arsenate or sodium arsenite did not alter oxygen uptake. Sodium arsenite did not greatly affect the phosphate uptake, but sodium arsenate uncoupled the phosphate uptake from oxidation of the substrate.

The effect of 2,4-dinitrophenol (DNP) on succinic oxidase was investigated over a concentration range from 0.003 to 6.7 micromoles per ml of reaction medium. Oxygen uptake was inhibited at all levels of DNP tried. At the lowest level of DNP, inhibition of oxygen and phosphate uptake was slight. At 0.5 micromoles of DNP, oxygen utilization was reduced approximately 50 per cent. Maximum phosphate uncoupling was observed between 0.3 to 0.5 micromoles of DNP.

Since oxygen and phosphate uptake occurred in the absence of magnesium ions, the effect of DNP at levels from 0.3 to 3 micromoles per ml of reaction medium was estimated in the absence of magnesium ions, and the effect of DNP on both oxygen uptake and phosphate was reduced. These data suggest that the primary effect of DNP is on the enzyme sequence converting inorganic phosphate to organic phosphate.

Gramicidin at 0.5 micrograms per ml of reaction medium reduced oxygen uptake approximately 25 per cent, but maximum phosphate uncoupling effect was observed at gramicidin levels of one or more micrograms.

Dicoumarol reduced oxygen uptake and interfered with phosphate incorporation at levels as low as 0.001 micromoles per ml of reaction medium. Oxygen uptake was reduced approximately 50 per cent at a dicoumarol level of 0.05 micromoles and was not further affected by higher levels. The maximum effect on phosphate occurred at a dicoumarol level of 0.1 micromoles and above.

Very low levels of pentachlorophenol (0.001 micromoles) reduced oxygen uptake approximately 50 per cent, and the phosphate uptake was reduced approximately 20 per cent. Maximum phosphate effect was observed in the presence of 0.01 micromoles of pentachlorophenol. At this level, however, oxygen uptake was reduced approximately 75 per cent.

Since oxygen uptake was inhibited by most of the oxidative phosphorylation uncouplers at levels which did not result in maximum effect on phosphate, caution will have to be exercised in interpreting the actions of other substances which may interfere with the phosphate or oxygen uptake in the bluegill liver mitochondria systems.

Of all the phosphate uncouplers investigated, all except sodium arsenite and sodium arsenate inhibited oxygen uptake to various degrees. Similarly, the effect on phosphate utilization varied with the concentration of inhibitor, and this effect seemed to be independent of the effect on oxygen uptake.

Five micromoles of sodium fluoride did not appreciably affect oxygen

uptake, but phosphate uptake was reduced. Higher fluoride levels inhibited oxygen uptake, and phosphate uptake was correspondingly reduced. Since the primary effect of high fluoride appears to be on oxygen uptake, a reduction in the oxidation of succinate would cause a decrease in the phosphate uptake. These data are in contrast to those of Kanungo and Prosser (1959) who reported that 1.0×10^{-3} M sodium fluoride was necessary for maximum phosphate uptake by goldfish liver mitochondria. Therefore, sodium fluoride was not routinely added to the reaction medium.

Malonate, a competitive inhibitor of succinic acid oxidation, was found to reduce oxygen uptake at levels of 20 micromoles. Further studies revealed, however, that oxygen uptake was reduced by 30 per cent at 0.1 micromoles of malonate and that levels of malonate of 1.0 to 1.5 micromoles completely abolished oxygen uptake. Similar results have been reported by Gumbmann and Tappel (1962).

Although oxidation of succinate by the bluegill liver systems apparently follows the usual scheme for the oxidation of succinate as shown by all other systems, there are some differences. Suitable mitochondrial preparations were obtained from less dense homogenizing media and by shorter periods of centrifugation. This also is indicated by the work of Brown and Tappel (1959) and Gumbmann and Tappel (1962), but other workers apparently did not investigate the effect of homogenizing media or the time of centrifugation on the tissue preparations.

In the work described above, all couplers used except sodium arsenite the oxidative phosphorylation un- and sodium arsenate inhibited oxygen uptake at levels in which uncoupling action was greatly reduced. Frequently, low levels of inhibitors were used and the effect on oxygen or phosphate was slight; the change from control vessels approached the experimental error of the experiments so that further work with lower levels did not appear feasible under such conditions.

The effect of malonate is interesting. If malonate blocks succinic oxidase activity by irreversibly combining with the active succinic acid enzyme sites, this would indicate that relatively few succinic acid sites may be available and that the turnover number of the succinic acid oxidase is relatively great.

In this regard, oxygen uptake by bluegill liver mitochondria in the presence of sodium amytal was increased about 90 per cent and in the presence of rotenone about 60 per cent (Hiltibran and Johnson 1965). Presumably, this effect would be due to the inhibition of DPN-linked oxidative steps preventing the formation of oxalacetic acid, a powerful inhibitor of succinic oxidase. These data also indicate, however, that bluegill liver mitochondria can rapidly oxidize succinic acid.

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FRACTIONATION OF HUMAN SEBUM FATTY ACIDS

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ABSTRACT. — Lipids extracted from adult male hair collected according to race and scalp condition have been saponified and the mixed fatty acids as such or following fractionation by way of the lead salts were esterified; the resulting methyl esters were submitted to distillation in spinning band columns. Such enriched fractions of human sebum fatty acids were required in special gas chromatographic studies. Proximate analyses are advanced for sebum acids based on the ester distillations.

The lipids elaborated by the sebaceous glands of the skin have been the subject of several investigations and the correlation of composition with metabolism and disease is of importance (Rothman, 1954; Montagna et al., 1963). The properties and constants of hair fat as a sebum source have been reported by this laboratory, among others (Krotoszynski et al., 1956).

The free fatty acids of lipids extracted from hair of adult males were reported to consist of normal saturated and unsaturated acids ranging in chain length from 7-22 carbon atoms on the basis of a distillation approach (Weitkamp et al., 1945); conventional methods, including preliminary studies with lead salt fractionation, were employed by others (Engman and Kooyman, 1934; Ricketts et al., 1951). Through chromatography, James and Wheatley (1956) analyzed the free fatty acids from forearm lipids initially extracted with acetone and noted the presence of odd- and even-numbered straight and branched chain saturated acids in addition to olefinic members. Comparable studies were reported by Boughton et al. (1959a; 1959b). A rather wide variation in free fatty acid content can be observed with sebum, hydrolytic decomposition occurring on storage and being aided in part by microorganism enzymes. Also, the nature of these fatty acids would depend on the component glycerides and sterol or wax esters hydrolyzed. Accordingly, greater attention was directed by this group to the total fatty acids obtained on saponification of sebum (Krotoszynski et al., 1956); gas chromatographic analysis of such mixtures from the hair fat of four normal human subjects was carried out by Haahti (1961).

In the present study, the fatty acids were removed following alkaline hydrolysis of sebum. The mixture as such, or after fractionation by way of the lead salts, was esterified and the esters distilled in spinning band columns. The resulting fractions were required in order to pin-point by subsequent gas chromatographic analysis several components normally present in minute amounts.

EXPERIMENTAL

For the isolation of mixed fatty acids from sebum and the determination of pertinent constants, the pro-

cedures described by Krotoszynski et al. (1956) were followed in all details. Iodine numbers were ascertained by use of bromine and sodium bromide in absolute methanol as the halogenating agent (Kaufmann and Baltes, 1936).

Hair pools from adult white and Negro full-headed and balding males were extracted with petroleum ether (boiling range: 30-60° C.) and the lipids saponified with 20% NaOH in 95% ethanol by heating for 24 hr on the steam bath. Dilution with water and removal of the unsaponifiable components with ethyl ether followed. The aqueous solution on acidification with sulfuric acid yielded the fatty acids. For removal of volatile acids (under 0.10%), the resulting mixture was steam-distilled until distillates were essentially free of acid as judged by titration with alkali. On cooling, the long-chain acids which came to the surface were removed by filtration, dissolved in ether, washed with water until free of mineral acid, and dried over anhydrous sodium sulfate. Processing yielded the mixed acids (MA).

Fractionation of MA by Way of the Lead Salts.—The procedure of Twitchell (1921) was applied for the enrichment of unsaturated fatty acids by lead salt formation. In one experiment, a boiling solution of 35 g lead acetate in 150 ml 95% ethanol containing 2.3 ml acetic acid was added to 50 g MA-WF-Series 2 in 350 ml 95% ethanol. The contents were boiled for 5 minutes, cooled to 25° C., then stored over ice for 20 hr. The solid salt mixture was filtered under vacuum, the filtrate F-S being stored for later use. Washing of the cake with two 10 ml portions of cold 95% ethanol and treatment with 15 ml of 7 N HCl followed. Removal of lead chloride and mineral acid yielded 26.4 g (52.4%) of solid acids (SA). The unsaturated liquid acids (LA) were recovered after vacuum concentration to one-third of the initial volume; yield: 21.6 g (43.3%). Table 1 presents yields and iodine numbers of the respective acid fractions starting with 25-50 g of MA.

Esterification of Fatty Acids.—

TABLE 1.—Separation of Sebum Mixed Fatty Acids by Lead Salts.[1]

Mixed Acids (MA)[2]		Solid Acids (SA)[3]		Liquid Acids (LA)[4]	
Code	Weight, g	%	Iodine Number	%	Iodine Number
WF–Series 2....	50.0	52.4	26.2	43.3	62.2
CF–Series 1....	50.0	51.6	28.9	46.3	73.8
CB–Series 1....	25.0	58.9	25.3	48.0	63.4
CB–Series 2...	25.0	59.0	31.3	50.0	77.1

[1] The acid numbers of the LA mixture generally ranged lower than the corresponding SA values. Thus, the numbers for SA and LA from WF-Series 2 were 192 and 134, respectively.

[2] In the coding which designates the origin of the sebum or the hair processed, C, W, F and B refer to white, Negro, full-headed and balding, in the order stated.

[3] Obtained from the lead salts insoluble in cold 95% ethanol.

[4] Prepared from acidification of ethanol-soluble lead salts.

MA or acids obtained by way of lead salt fractionation (SA and LA) were converted into esters by treatment with absolute methanol in the presence of hydrogen chloride. Invariably, two layers ocurred at the conclusion of the heating period, the lower one containing up to 25% of the total ester content. As the two phases for a given esterified mixture were quite similar in properties, preliminary separation and individual processing was abandoned. Thus, the iodine numbers for the esters in the lower and upper layers from MA-CB-Series 2 were 25.6 and 27.8, respectively. In one experiment, 46.4 g of LA, obtained from CF-Series 1 (Table 1), in 175 ml absolute methanol was saturated with a slow stream of hydrogen chloride for 10 min, the mixture refluxed for 19 hr, then freed of methanol under vacuum and 50 ml of ether added. Washing with five 50 ml portions of 5% sodium bicarbonate and four 15 ml volumes of water followed. By removal of ether from the dried solution, 46.3 g of esters resulted.

Spinning Band Column Distillation of Methyl Esters.—A total of 31.6 ml (30.2 g) of esters from MA-WF-Series 1 was distilled in a Podbielniak column (90 cm x 5 mm) with a band rotation of 3250 rpm and at a pressure of 1 mm. The throughput was 20 drops per minute or 18 ml/hr and the product rate or take-off comprised 0.5 ml/hr which was later decreased to 0.35 ml/hr. A total of 69 fractions was collected, with a recovery of 95.0%. The indices of refraction and iodine numbers were ascertained as shown in the curves of Figure 1. The hold-up which amounted to 0.91 g yielded 0.73 g of fatty acids on saponification; the still residue was partly carbonized.

Methyl esters derived from the liquid acids on lead salt fractionation of MA-WF-Series 2 were distilled in a Nestor spinning band column (76 cm x 10 mm) at a pressure of 0.8 mm and a band rate of 1550 rpm. From a charge of 22.8 ml (20.0 g), eighteen 1 ml fractions were collected, accounting for 18.2 g or a 91.0% recovery. The corresponding curves are shown in Figure 2. The densities (d_{20}^{20}) of Fractions 2, 4, 7, 8, 11 and 14 were 0.8632, 0.8628, 0.8604, 0.8604, 0.8599 and 0.8661, respectively.

Paper Chromatography of Volatile Acids.—The volatile acid portions obtained on steam distillation of the aqueous saponification mixtures were neutralized and concentrated to dryness on the steam bath. Several samples were dissolved in water, acidified with a few drops of concentrated hydrochloric acid and applied to paper strips for chromatographic separation by the procedure of Duncan and Porteous (1953). In all instances, the most prominent spot was due to acetic acid, the R_f value averaging 0.12.

Discussion

For fractionation of MA esters toward distillation and use in special gas chromatographic separations, the efficacy of the lead salt method was explored. However, this procedure is replete with inherent difficulties as can be noted from the constants for the "saturated" groups of acids (Table 1). With the latter, salts of the olefinic acids are precipitated from cold ethanol along with

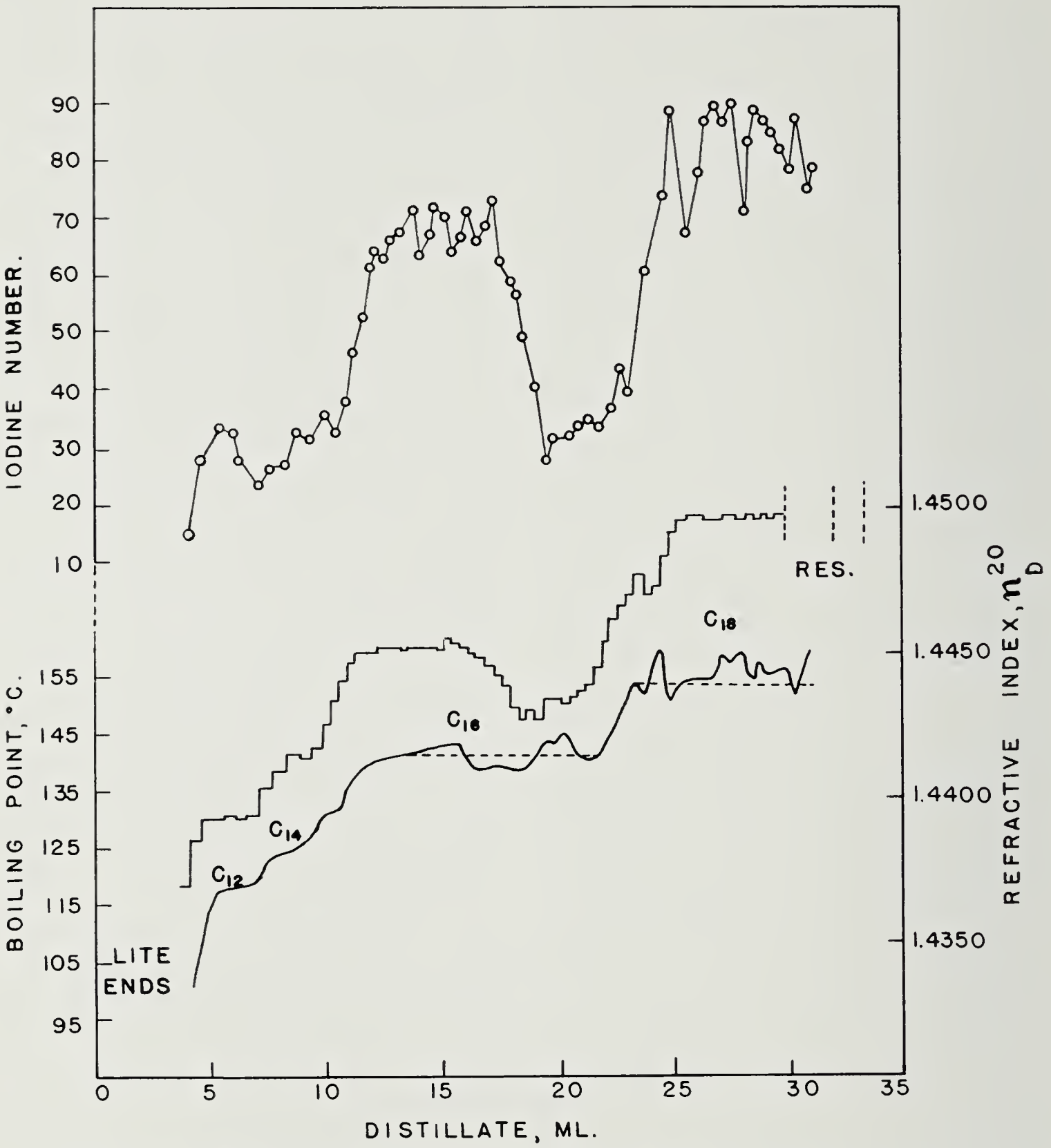

FIGURE 1.—Indices of refraction and iodine numbers for ester cuts from the mixed acids (MA) derived from WF-Series 1 with boiling points at a pressure of 1 mm. The dotted line on the distillation curve represents more idealized boiling ranges.

the saturated long-chain members. Also, homologs of shorter chain length, C_{12}—C_{16}, are incompletely precipitated. The neutralization equivalents of the acids from the ethanol-soluble salts invariably ranged lower than those of the "saturated" or solid acids. In this regard, no marked improvement was evident when lithium salts were substituted and in common with methods involving salt formation, complexes with urea or thiourea produced no clean-cut fractionation of MA, although many products were isolated. Since the iodine number of

the most saturated mixtures obtained by these procedures were similar, indicating no greater advantage for any one method, the acids were separated by way of the lead salts prior to esterification of LA or the "unsaturated" acids.

An effective distillation of MA esters was performed with a pool originating from white full-headed male sebum (WF-Series 1) in a spinning band column at a pressure of 1 mm. The outstanding plateaus noted in the boiling curve for the resulting 69 cuts (Fig. 1) were also reflected in the indices of refraction and iodine numbers. The predominent carbon chain represented by a given plateau was ascertained by comparison with literature values and nomographs. Fractions richer in saturated esters showed lower values with concomitant variations in refractive indices. From the data, one may assume that esters with more than one double bond are present in the C_{18} mixtures. However, assuming that the unsaturated acids in each group all contained only one double bond, a proximate composition was derived for the methyle exters as shown in Table 2; odd-carbon homologs as such were deleted in the groups although small amounts of such acids do occur based on gas chromatography and as might be implied from the distillation curve. Whereas the presence of homologs containing more than eighteen carbon atoms could not be adequately justified in this case, they were undoubtedly present in the light of constants obtained with esters from similar still residues.

Further WF esterified fractions but of greater olefinic acid content were derived from the liquid acids (LA) of the lead salt treatment. A proximate analysis based on distillation behavior (Fig. 2) is given in

TABLE 2.—Proximate Analyses of Methyl Esters from WF Sebum Pools.[1]

Chain Length[2]	Percent of Total	Unsaturation[3] in Fraction, %	Unsaturation[3] in Total, %
MA-WF-Series 1			
12	1.7	14.1	0.24
14	21.2	27.8	5.9
16	47.8	48.2	23.0
18	25.3	86.8	21.9
Bottoms	9.0		
LA-WF-Series 2			
14	2.9	12.1	3.5
14	13.5	42.8	5.7
16	42.2	74.3	31.3
18	29.7	101.5	25.0
Bottoms	7.2		

[1] The values are based on the data of Figures 1 and 2.
[2] Small amounts of odd-carbon acids are also present in the main groups.
[3] Calculated on the basis that only mono-olefinic acids are present.

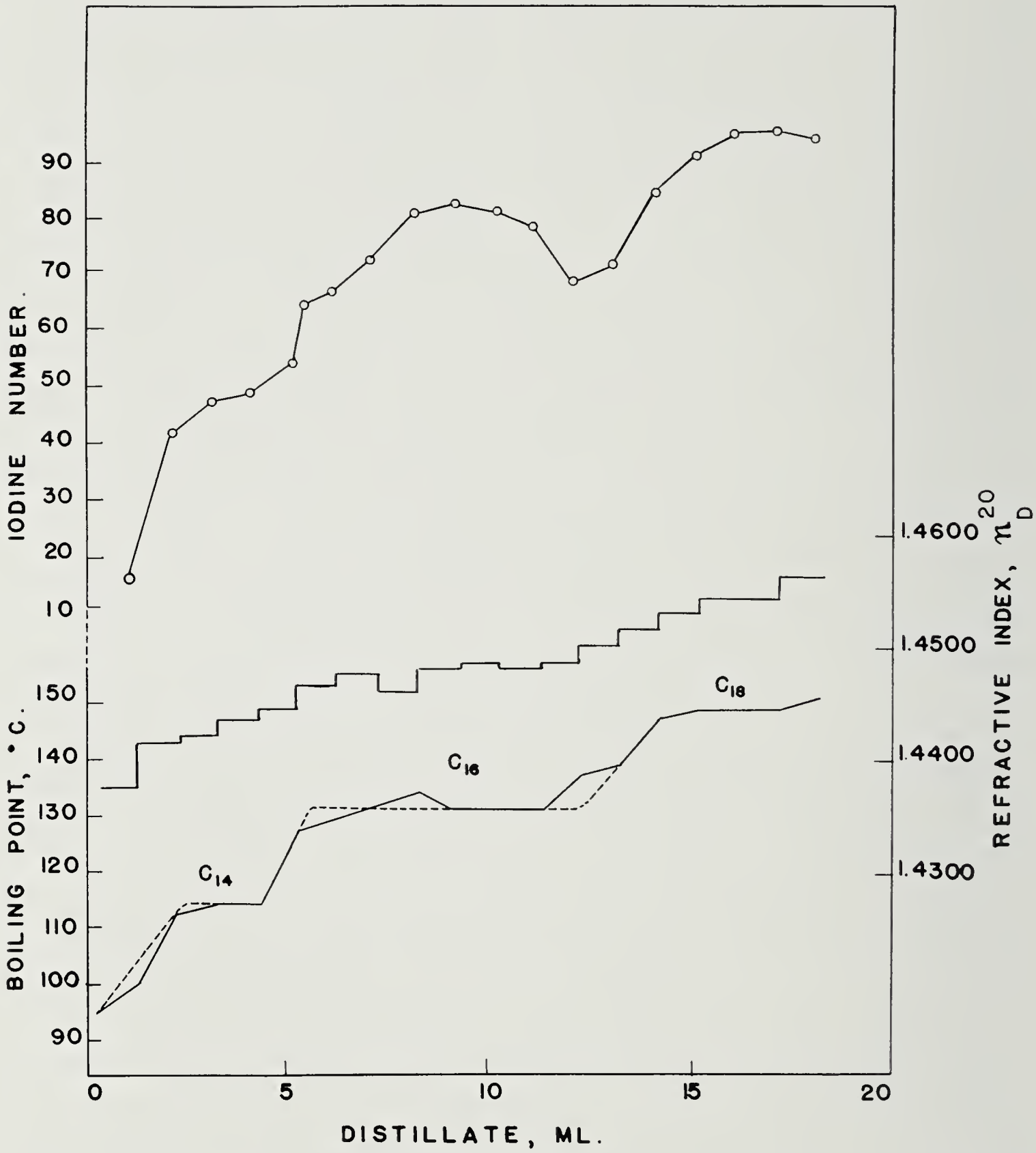

FIGURE 2.—Refractive indices and iodine numbers for ester fractions from LA-WF-Series 2 with boiling points at 0.80 mm pressure. The liquid or "unsaturated" acids are derived from lead salt fractionation of MA.

Table 2. The C_{14}-moieties occurred at a somewhat lower level and the percentage unsaturation of each of the main groups increased markedly in contrast to the MA esters (Table 2). Homologs with less than 14 atoms were slightly, if at all, enriched with essentially no gross alteration in unsaturation.

The minute amounts of acids removed by steam distillation of the acidified saponifiable mixtures were shown by paper chromatography to consist principally of acetic acid. This is in line with the findings of Brouwer and Nijkamp (1952) on the volatile acids of hair grease obtained from a number of animals and

also man. One or two acids appeared to be characteristic of a species, although most of the homologs of the series could be detected. In human hair fat, acetic and caprylic acids were predominant, the remaining members occurring in traces. As the C_8-acid lies at the extreme limit of steam-distillability, its recovery was probably too small for adequate identification in the present instance.

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A LATE PLEISTOCENE HERPETOFAUNA FROM MISSOURI

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ABSTRACT.—A salamander, frog, legless lizard, and at least 10 species of snakes from a cave near St. Louis, Missouri, may represent a herpetofauna of interglacial or recessional time in the late Pleistocene.

A large number of Pleistocene amphibian and reptile bones were collected from a cave near St. Louis by Mr. Ronald D. Oesch of Kirkwood, Missouri. Through the kindness of the collector I have been permitted to study this assemblage of 1,894 snake vertebrae and a few amphibian and lizard remains.

The following information has been supplied by Mr. Oesch who plans to describe the mammalian remains, the exact location, and the geology of the deposit in a future publication. The site is in a cave called Crankshaft Pit, which is about twenty miles southwest of St. Louis, Missouri. The cave developed in Ordovician Joachim Dolomite, and is entered through a two by three foot opening that leads into a 59-foot vertical shaft. The animals were evidently trapped by falling into the shaft. The bone bed is located in a filled crevice about 30 feet from the bottom of the shaft in the floor of a horizontal tunnel. The unstratified matrix may represent a mud flow into the crevice. The fossils came from about 105 gallons of this matrix that was removed from the cave and washed. In the concentrate were the remains of the extinct armadillo, *Dasypus bellus*, and tapir bones. Thus, a Pleistocene age is indicated.

MATERIALS AND METHODS

Disarticulated amphibian and reptile skeletons housed at Illinois State University as well as specimens donated by G. B. Rabb of Brookfield, Illinois, and by G. Hartz of Chicago, Illinois were utilized as comparative material. All measurements are in millimeters.

Intercolumnar, ontogenetic, and individual variations combine to present a bewildering array of problems in the identification of individual snake vertebrae. Nevertheless, several authors have been able to assign well-preserved vertebrae to the generic level, and often specific identifications are possible (see Holman, 1962 and 1963; Brattstrom, 1954 and 1964; and especially Auffenberg, 1963). Usually, fragmentary vertebrae, caudals, and those from the anteriormost or posteriormost parts of the remaining column are not designated taxonomically.

The fossils have been deposited in the collections (abbreviation CM) of the Department of Biology of Central Missouri State College, Warrensburg, Missouri.

Description of the Specimens

Ambystoma maculatum (Shaw). —Material: 1 body vertebra, CM 260. Tihen (1958) has discussed vertebral characters of the species groups of *Ambystoma,* and Holman (1964) has detailed differences between the body vertebrae of *Ambystoma texanum* and *A. maculatum.* The fossil ambystomatid vertebra has the elongated shape of those of *A. texanum* and *A. maculatum* (Tihen, op. cit.). Unfortunately, the tip of the neural arch is broken, but appears to have extended at least as far posteriorly as the ends of the postzygapophyses. The length of the vertebra is 5.5; thus the fossil apears to represent *A. maculatum* (see Holman, op. cit., p. 74, Table 1).

Rana sp. — A fragmentary body vertebra (CM 261) representing a rather small individual of the genus *Rana* is not assigned to species.

Ophisaurus ventralis (Linnaeus). Material: 1 body vertebra (CM 262) of an adult individual. The three species of *Ophisaurus* in the United States may be distinguished from one another by vertebral characters (Auffenberg, 1955, and Etheridge, 1960 and 1961). The angle between the posterior border of the neural spine and the longitudinal axis of the centrum in the fossil is 80 degrees. It ranges from 65-84 degrees in *O. ventralis,* 45-65 degrees in *O. attenuatus,* and 78-91 degrees in *O. compressus* (Etheridge, 1961, p. 180). The ratio between the length of the centrum of the fossil (3.9 when measured from the greatest depth of the glenoid cavity to the most posterior extent of the condyle) divided by the least width of the neural arch (2.7) is 1.44. This ratio ranges from 1.12-1.55 in *O. ventralis,* 1.10-1.40 in *O. attenuatus,* and 1.50-2.00 in *O. compressus* (Etheridge, loc. cit.). The fossil represents *O. ventralis.*

Ophisaurus ventralis has an odd distribution today. It is principally distributed in the southeastern United States, but there are isolated records from southeastern Oklahoma and east-central Missouri (McConkey, 1954, p. 139, fig. 3). The sole Missouri records (one from Jefferson County, and one from St. Louis) are from localities that are near the Crankshaft Pit fossil site.

Thamnophis sirtalis (Linnaeus). —Material: 52 precaudal vertebrae, CM 263.

Thamnophis cf. *Thamnophis proximus* (Say).—Material: 25 precaudal vertebrae, CM 264.

Holman (1962) discussed the specific identification of isolated *Thamnophis* vertebrae. At this time he considered *T. sauritus* and *T. proximus* to be subspecifically related. Rossman (1962) has shown that both are valid species. Thus, vertebral characters given by Holman (op. cit.) for "*T. sauritus*" apply to both *T. sauritus* and *T. proximus.*

Heterodon platyrhinos Latreille. Material: 15 precaudal vertebrae, CM 265. The three living species of *Heterodon* (*H. simus, H. nasicus,* and *H. platyrhinos*) may be separated on vertebral characters (Holman, 1963).

Coluber sp.—I am unable to separate the vertebrae of modern *Coluber constrictor* from those of *Coluber flagellum* on any qualitative or quantitative character. The 463 vertebrae (CM 266) assigned to *Colu-*

ber may represent either one or both species.

Elaphe vulpina (Baird and Girard).—Material: 72 precaudal vertebrae, CM 267. Many of the fossils are in excellent condition. Several sections of articulated column that appear to represent a single large individual are present.

Elaphe sp.—These 131 precaudal vertebrae (CM 268) represent either *E. guttata* or *E. obsoleta* or perhaps both species.

Members of the genera *Elaphe, Pituophis,* and *Lampropelitis* have similar vertebral characteristics. Nevertheless, *Pituophis* may be distinguished from *Elaphe* and *Lampropeltis* on the basis of the indented anterior edge and greater height of its neural spine. There is variation in the shape of the neural spine in the species of *Elaphe* and *Lampropeltis,* but the condition found in *Pituophis* is never seen. *Pituophis catenifer* (*Pituophis melanoleucus sayi* of some authors) may be distinguished from *Pituophis melanoleucus* in that the latter species has higher neural spines.

Elaphe and *Lampropeltis* are more difficult to separate. In the modern species of *Lampropeltis* available to me the neural arch is usually less vaulted than in species of *Elaphe. Lampropeltis getulus* may usually be distinguished from the larger species of *Elaphe* and *Lampropeltis* by a combination of rather subtle characters. In *L. getulus* the vertebrae are quite robust with thick neural spines and neural arches. The hemal keels and subcentral ridges are usually quite strong, and the valleys between the subcentral ridges and the hemal keel are usually very deep. Moreover, in most specimens the neural arch is flattened, although occasionally it may be slightly vaulted. Vertebrae of *Lampropeltis doliata, L. zonata,* and *L. pyromelana* have very low neural spines; this coupled with their small size separates them from other species of the *Elaphe-Lampropeltis* complex. The vertebral structures of *Lampropeltis calligaster* are similar to those of some species of *Elaphe,* but most *L. calligaster* have stronger hemal keels and subcentral ridges than do species of *Elaphe.*

Although some authors have identified individual vertebrae as *Elaphe guttata* and *E. obsoleta* I can not find characters that separate these two species. *E. vulpina* may be distinguished from the former two species by its much lower neural spine. This character holds in both large and small specimens.

Pituophis catenifer (Blainville).—Material: 17 precaudal vertebrae, CM 269. Characters for distinguishing the vertebrae of this species have been discussed in the previous section.

Lampropeltis getulus (Linnaeus).—Material: 27 precaudal vertebrae, CM 270.

Lampropeltis doliata (*Linnaeus*).—Material: 126 precaudal vertebrae, CM 271. Some of these vertebrae represent a rather large specimen or specimens of the milk snake.

Characters for distinguishing the vertebrae of *L. getulus* and *L. doliata* have been discussed in the *Elaphe* section.

Crotalus horridus Linnaeus.—Material: 24 precaudal vertebrae, CM 272. One or more small specimens, and at least one very large speci-

men are represented by the fossils.

Crotalus horridus may be distinguished from *Agkistrodon piscivorus* and *A. contortrix* in that the pits on either side of the cotyla of the latter species are more deeply excavated. In *Sistrurus catenatus* the prezygapophyses are tilted upward to a much greater degree than in *Crotalus* and *Agkistrodon*. Moreover, a tiny spine is usually visible just anterior to the neural spine in *Sistrurus*. This spine is lacking in *Crotalus* and *Agkistrodon*. *Crotalus horridus* is the only viperid snake represented in the Missouri fossil fauna.

Discussion

All of the genera and species of amphibians and reptiles from the Crankshaft Pit represent forms that are living today. Moreover, all of the species identified occur in or near the vicinity today (Conant, 1958).

The fossil herpetofauna is mainly a terrestrial one. Only a few forms (*Ambystoma maculatum*, *Rana* sp., *Thamnophis sirtalis*, and *T.* cf. *proximus*) indicate the proximity of moist or aquatic conditions, and these species are represented by only a few bones. The ecological conditions at the time of the accumulation of the bones were probably not much different from those of the area today, with most of the animals being accidentally derived from hardwood forests and glades near the cave.

Elaphe (*guttata* or *obsoleta*) may have entered the cave searching for bats. Both species of *Elaphe* are good climbers. Dr. Charles J. Flora of Western Washington State College (personal communication) has observed *Elaphe guttata* entering and leaving Grant's Cave (a well-known bat locality in Alachua County, Florida) by means of a 30 foot vertical shaft. Moreover, Carr (1940) reports several *Elaphe q. quadrivittata Elaphe obsoleta quadrivittata* frequenting a cave inhabited by thousands of bats, in Citrus County, Florida.

A glacial climate is definitely not indicated by the herpetofauna. Considering the presence of the armadillo, *Dasypus bellus*, an interglacial or recessional stage is suggested. Based on the striking similarity of the herpetofauna to one that could be found in or near the area today. It seems likely that the deposit represents late Pleistocene times.

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SACRAL FUSIONS IN SOME NEOTROPICAL *RANA*

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ABSTRACT. — Sacral-presacral fusion occurs with a higher incidence in the frogs of the *Rana palmipes* group than in any other species group of new world *Rana*.

The significance of sacral fusions in the anurans has not been clearly understood. Noble (1931) and subsequently other authors have concluded that there was no functional significance. However, these fusions involved, for the most part, fusions of presacral vertebrae or of the sacrum and the coccyx (urostyle).

Holman (1963) has recently studied a large and variable series of anurans (Ascaphidae, 1; Discoglossidae, 2; Pipidae, 3; Rhinophyrynidae, 5; Pelobatidae, 36; Leptodactylidae, 16; Bufonidae, 148; Atelopodidae, 2; Centrolenidae, 1; Hylidae, 182; Microhylidae, 13; and Ranidae 119.) He found that such fusions as well as those which were obviously abberant were exceptional cases—not the rule.

In this report I will concern myself with the American *Rana*. The material studied includes the following:

Rana areolata 45, *R. aurora* 2, *R. boylei* 4, *R. capito* 2, *R. cascadae* 8, *R. catesbeiana* 48, *R. clamitans* 25, *R. grylio* 15, *R. heckscheri* 5, *R. maculata krukoffi* 1, *R. m. maculata* 6 (by x-ray), *R. palmipes* 24, *R. palustris* 22, *R. pipiens pipiens* 60, *R. p. sphenocephala* 25, *R. p. berlanderi* 4, *Rana pipiens subsp.* (Mexico) 10, *R. pretiosa luteiventris* 8, *R. pustulosa* 7, *R. septentrionalis* 1, *R. sierramadrensis* 1, *R. sylvatica* 8, *R. tarahumarae* 1, *R. warschewitschii* 16. J. Alan Holman (in *litt.*) has told me of three additional *R. palmipes* with a presacral fusion.

Zweifel (1955:210) studied several *Rana* skeletons in the course of his study of the *Rana boylei* group. He studied sacrals of *Rana aurora* 8, *R. boylei* 28, *R. cascadae* 10, *R. muscosa* 19, *R. pipiens* 4, *R. pretiosa* 1 and *R. tarahumarae* 4.

The American *Rana* studied by Holman (loc. cit.) were: *R. areolata* 2, *R. aurora* 1, *R. boylei* 2, *R. capito* 1, *R. cascadae* 2, *R. catesbeiana* 5, *R. clamitans* 9, *R. grylio* 4, *R. heckscheri* 3, *R. palustris* 1, *R. pipiens* 78, *R. sylvatica* 7. Thus 530 new world *Rana* are available for comment.

Of the 78 skeletons studied by Zweifel (loc. cit.) none showed a presacral-sacral fusion. This is evidenced by Zweifel's remarks concerning a postsacral fusion—". . . [one *boylei* was] unusual in having the urostyle and sacral vertebra fused." One can be fairly sure that if a presacral-sacral fusion had been evident Zweifel would have commented on it.

The species groups of neotropical and to a lesser extent nearctic *Rana* have been outline by Zweifel (1955, 1956, 1957, and 1964) and myself (MS). The *Rana palmipes* group includes *R. maculata* subspp., *R. miadis*, *R. sierramadrensis*, *R. sinaloae*, *R. palmipes* subspp., *R. taylori*, *R. vibicaria* and *R. warschewitschii* (Zweifel 1956 and 1964). The *Rana pipiens* group includes *R. dunni*, *R. megapoda*, *R. montezumae* and *R.*

pipiens as well as several species in the eastern United States. The *Rana catesbeiana* group is represented only by *R. catesbeiana* in the area concerned. *R. clamitans, R. grylio, R. heckscheri,* and *R. septentrionalis* are members of this group whereas *R. capito* and *R. palustris* are members of the *R. pipiens* group.

The fused sacral-presacral of *R. palmipes* is illustrated in Figure 1.

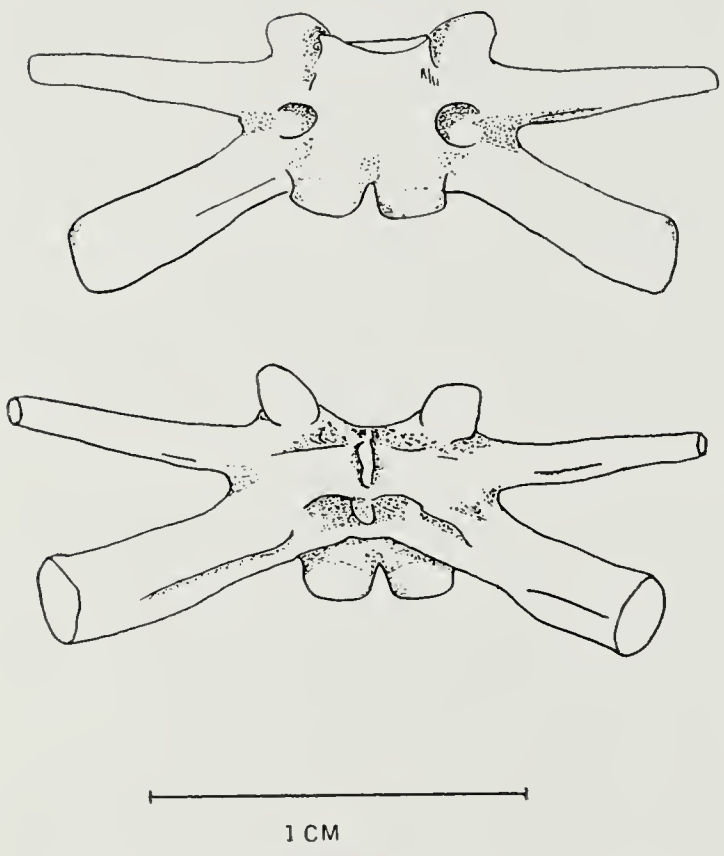

FIGURE 1.—Dorsal (A) and ventral (B) views of fused sacral-presacral vertebrae in an adult *Rana palmipes* (San Andres Tuxtla, Veracruz, Mexico.)

The fusion is symmetrical and the rule—not the exception. The data in Table 1 clearly illustrates that the frogs of the *R. palmipes* group are nearly unique in the high frequency of sacral-presacral fusion. The frogs of the *R. boylei* group also show some fusion and this might be expected as they are closely related. In the other species which showed the condition, the percentages are below 5%—in all but one case. In this instance, *R. capito,* the

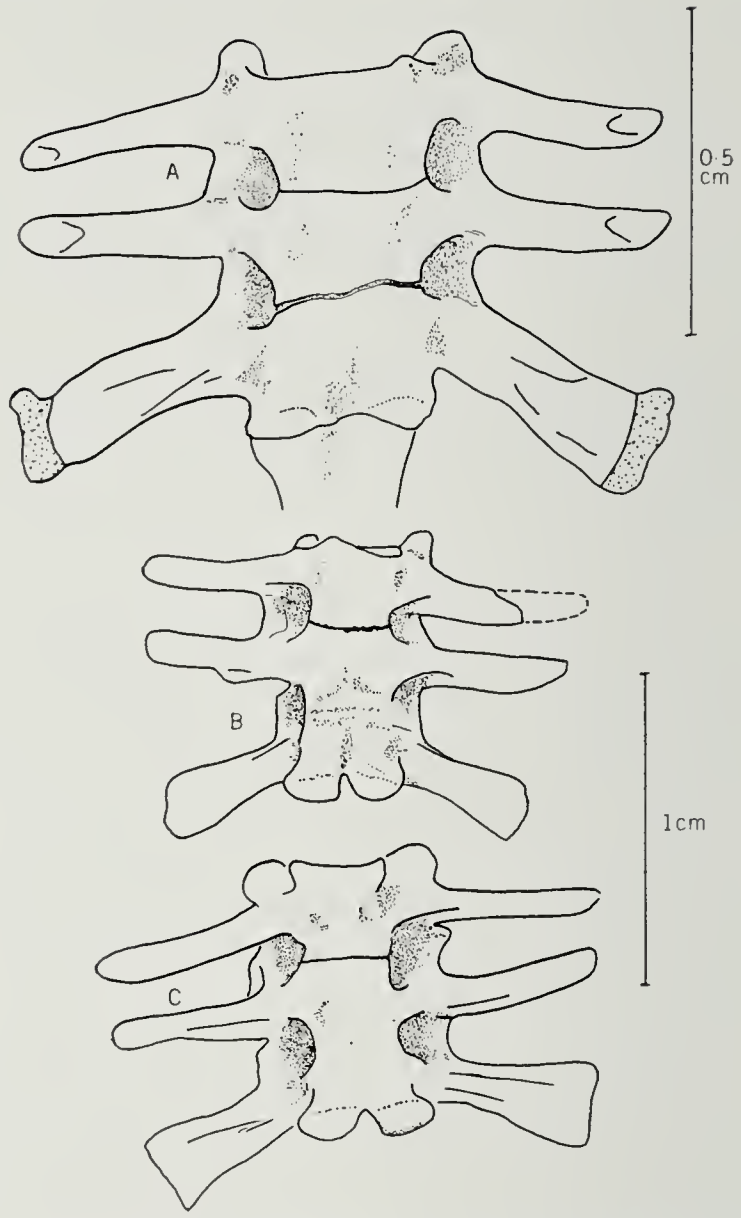

FIGURE 2.—Ventral view of posterior portion of vertebral column in *Rana pustulosa.* (A) UIMNH 32185, 52 mm snout-vent length; (B) UIMNH 32251, 73 mm snout-vent length; (C) UIMNH 40875, 85 mm snout-vent length.

data was skewed because so few individuals were seen. In the closely related *R. arcolata* (considered conspecific by some workers, e.g., Conant, 1958), such fusions were not seen in a large series.

The *R. palmipes* group is morphologically very close to the *R. boylei* group, particularly the two southernmost species, *R. tarahumarae* and *R. pustulosa. Rana pustulosa* is superficially very much like *R. sinaloae,* the northernmost form of the *R. palmipes* group.

In one specimen of *R. tarahumarae,* a very large adult, an obvious

TABLE 1.—Incidence of sacral-presacral fusions in new world *Rana*.

Species	Number with fusion	Number examined	Percentage fused
R. capito	1	3	33.3
R. clamitans	1	34	2.9
R. catesbeiana	1	53	1.9
R. maculata (krukoffi)	1	1	100.0
R. maculata (maculata)	6	6	100.0
R. palmipes (adults)	24	24	100.0
R. pipiens	5	179	2.8
R. palustris	1	23	4.3
R. tarahumarae	½[1]	5	10.0
R. pustulosa	2	7	28.6[2]
R. sierramadrensis	1	1	100.0
R. warschewitschii	16	16	100.0

[1] Fused on one side only—see text.
[2] Fused only in old adults—see text.

fusion was seen on one side of the sacral-presacral suture whereas it appeared that the other side was not fused. Zweifel (loc. cit.) found no fusions in his specimens. The seven *R. pustulosa* studied represented three age classes—young (52-53 mm snout-vent), intermediate (73-74 mm snout-vent), and large adults (81-85 mm snout-vent). The fusion is clearly an ontogenetic characteristic. In the youngest individuals (Fig. 2) a broad suture is in evidence and the sacral vertebra moves readily in respect to the presacral. In those specimens of middle age where the suture is still evidence although there is some fusion, it was possible to break the bones apart with relative ease. The older specimens showed no evidence of a suture and fusion is complete. In those frogs of middle age, when the suture was broken the diplasiocoelous condition was still clearly evident. It is not known if the fusion is a result of building up of the bone on the surface or a fusion at all surfaces. There seemed to be a deposition of osseous material anterior to and posterior to the suture in the middle aged frogs.

In *Rana palmipes,* specimens 60 mm in snout-vent length showed complete fusion (Fig. 3) as did all larger individuals examined (25 specimens) whereas smaller individuals (ca. 43 mm) showed a non-fused condition. It seems likely, although sufficient numbers of specimens are not available to test the hypothesis, that in all species of the *Rana palmipes* group the sacral-presacral fusion is an ontogenetic characteristic and that this feature expresses itself early in the ontogeny of the members of this group and later in the members of other groups.

That this may well be the case in most new world *Rana* is strongly suggested by the remarks of Holman (loc. cit.) who noted the very high incidence of fusion in *Rana catesbeiana* from a Pleistocene locality in

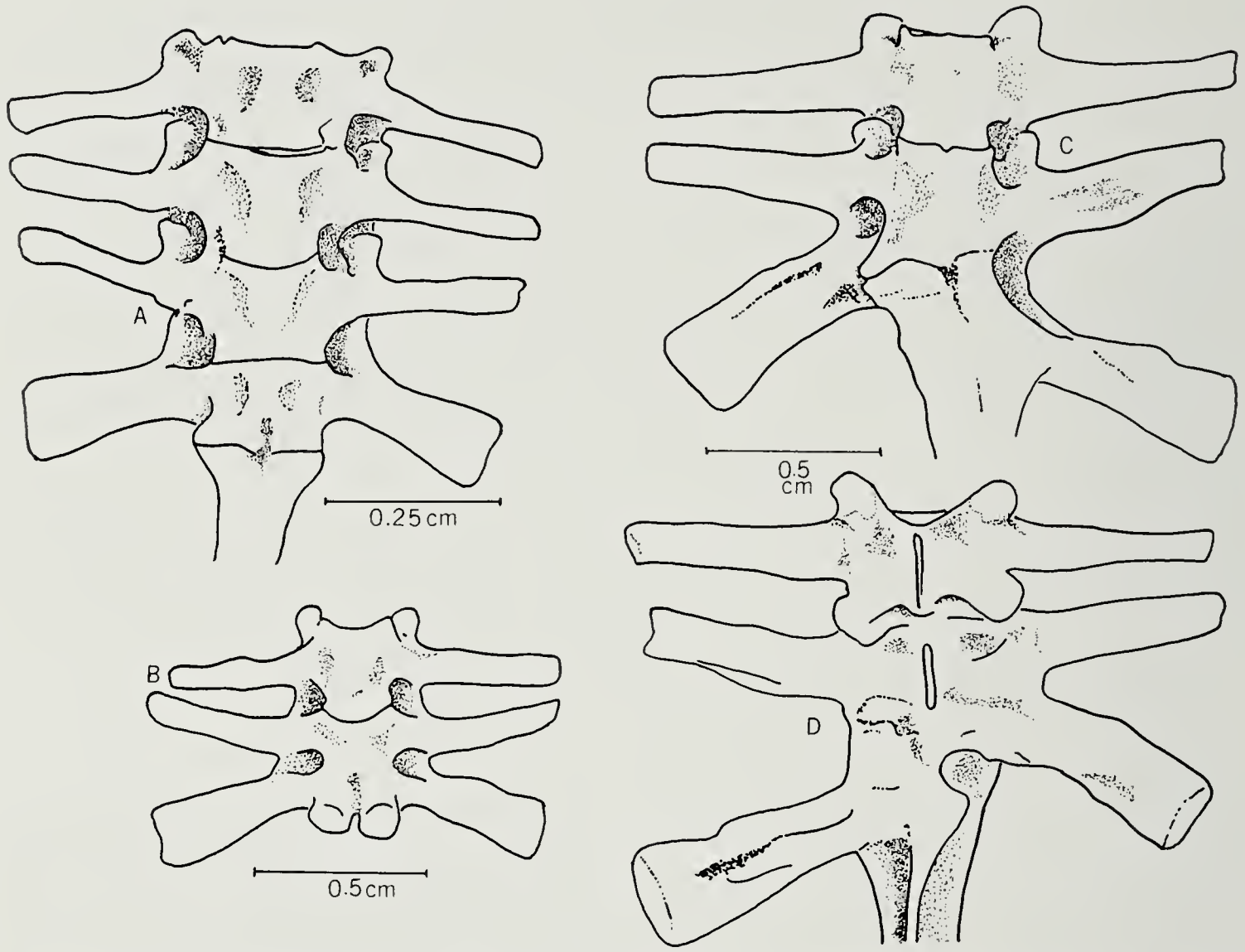

FIGURE 3.—Ontogenetic fusion of sacral and presacral vertebrae in *Rana palmipes*. (A) UIMNH 51175, 43 mm snout-vent; (B) UIMNH 9851, 60 mm snout-vent; (C) UIMNH 9857, 90 mm snout-vent, ventral view illustrating anomalous sacral diapophysis; (D) dorsal view of C.

Florida. Dr. Holman has kindly permitted me to examine the specimens and judging from the sizes of certain bones, the fossils represent, in nearly every case, individuals of snout-vent measurements of about 200 mm (8 inches) or more.

However, in the cases of fossils of *Rana pipiens* in which the fused condition is seen, the percentages of fusion are much lower in cases where adequate samples are available and correspond favorably to the percentages obtained from samples of Recent specimens. Also, the fossil *R. pipiens* are not extra large frogs. In the case of this species, it seems more likely that the fusion results from a similar or the same phenomenon which produces it in Recent frogs of average or moderate size.

The functional significance of the sacral-presacral fusion in frogs is not clearly apparent. In mammals several vertebrae fuse to form the sacrum and in birds the synsacrum serves for greater stability and motility.

If the evidence from the fossil record is real as well as apparent, this, coupled with the ontogenetic development of the sacral fusion, would seem to indicate that the condition arises as an adaptation to the stresses created by increased weight and size of older specimens. Greater forces would be applied, in jumping and landing, to the sacrum in larger

individuals than in smaller specimens of that species. Thus a larger and more rigid sacrum would provide a pivot in an area of relatively little restricted movement. Whitting (1964) has illustrated some of the limits to movement in the functional unit composed of the vertebral column, urostyle and ilia. Fusion of some vertebrae to each other or fusion of the sacrum to the urostyle would reduce some of this movement and lend to greater stability. Fusion of the sacral and presacral vertebrae seems to be the only means for a frog with cylindrical sacral diapophyses to approach the condition of a frog with expanded diapophyses. Of interest is the fact that very few ranid frogs exhibit expanded diapophyses.

Summary

The sacral-presacral fusion as defined by Holman (1963) occurs with a higher incidence in the frogs of the *Rana palmipes* group than in any other species group of new world *Rana*. It is seen only as a rarity in the *pipiens, catesbeiana, sylvatica* or *auroa* species groups or in very old specimens (only fossils as far as is known at this time). The fusion occurs as an ontogenetic feature in the frogs of the *boylei* and *palmipes* groups and is more characteristic of the Mexican species of the former group than the Pacific coast species of that group. Use of this feature in creating supraspecific taxa (e.g. *Anchylorana*) as Taylor (1942) did is not to be advised.

Acknowledgments

Dr. Hobart M. Smith permitted me to dissect numerous *Rana* in the collections of the University of Illinois Museum of Natural History. For the loan or gift of specimens I am indebted to Mr. Monty Bullard, Portland, Oregon, Dr. J. Alan Holman, Illinois State University, Normal, Mr. J. Howard Hutchison, University of Oregon, Eugene, Mr. Thomas H. Fritts, and Dr. H. M. Smith, University of Illinois, Urbana. The curators of the collections at the Chicago Museum of Natural History and the Museum of Natural History, University of Kansas, have kindly permitted me to examine specimens in their care. Drs. Holman and Smith have discussed my paper with me and offered valuable suggestions. My thanks to all of these.

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THE PARTIAL MOLAL VOLUME OF SODIUM MONOFLUOROPHOSPHATE IN AQUEOUS SOLUTION AT 25°C

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E. St. Louis

ABSTRACT.—The density of aqueous solutions of sodium monofluorophosphate has been measured at 25°C over the concentration range 0.4 to 2.0 molal. The partial molal volume is a linear function of the square-root of the molality and is defined by the equation

$$\overline{V}_2 = 15.6 + 17.5 \sqrt{m}.$$

Similarities between monofluorophosphates and sulfates (Lange, 1950) have been unjustifiably interpreted to mean that the sulfate and monofluorophosphate ions behave similarly in aqueous solution (Devonshire and Rowley, 1962). We have measured the densities of aqueous solutions of sodium monofluorophosphate, Na_2PO_3F, from which the apparent molal volume of the salt is calculated and the partial molal volume ultimately determined.

Using the data for partial molal volumes we are able to compare these isoelectronic and isomorphic anions, sulfate and monofluorophosphate, and qualitatively compare their relative hydration in aqueous solution.

PROCEDURES

Density measurements were made in Sprengel-type pycnometers at 25.00 ± 0.01° C on analyzed samples of sodium monofluorophosphate of 97.0% purity. Pycnometer weighings were made with calibrated weights corrected for the buoyancy of air. A counter-balance was constructed from glass to have approximately the same volume and surface area as the pycnometer to compensate for the buoyancy of the pycnometer.

RESULTS

Table 1 lists the densities, d, and apparent molal volumes, $\varnothing_v$, for aqueous solutions of sodium monofluorophosphate at 25° C. The apparent molal volumes were calculated using the equation (Harned and Owen, 1950)

$$\varnothing_v = \frac{1000\ (d_o - d)}{m\ d\ d_o} + \frac{M_2}{d} \qquad (1)$$

where m is the molality of sodium monfluorophosphate, M_2 its molecular weight and d and d_o the densities of solution and solvent respectively. Masson (Harned and Owen, 1950) observed that the apparent molal volume as a function of the square-root molarity could be expressed by the equation

$$\varnothing_v = \varnothing_v^0 + S_v \sqrt{c} \qquad (2)$$

TABLE 1.—Densities and apparent molal volumes of aqueous solutions of sodium monofluorophosphate at 25°C.

m, moles per 1000g solvent	density, g/cm³	Apparent molal volume, $\varnothing_v$, CM³/mole
2.1199	1.2182	32.309
1.9218	1.1985	31.604
1.6974	1.1788	31.040
1.3994	1.1504	29.637
1.1974	1.1302	28.738
0.99702	1.1104	26.967
0.80166	1.0890	26.556
0.59457	1.0670	24.428
0.40160	1.0451	22.950
0.38953	1.0438	22.772

for many electrolyte solutions. The relation often extends to concentrated solutions. In their expression $\varnothing_v^0$ is the limiting molal volume and S_v is the slope of the line. A least-squares evaluation of our data, in which we have chosen to express concentration in terms of molality (MacInnes and Dayhoff, 1952), yields the result

$$\varnothing_v = 15.6 + 11.7 \sqrt{m} \qquad (3)$$

where the value of the limiting molal volume of sodium monofluorophosphate is 15.6 ± 0.9 cm³/mole.

The partial molal volume of the solute may be expressed (MacInnes and Dayhoff, 1952) by

$$\overline{V}_2 = \frac{\partial v}{\partial m} = \varnothing_v + m \frac{\partial \varnothing_v}{\partial m} \qquad (4)$$

so that from our data

$$\overline{V}_2 = 15.6 + 17.5\sqrt{m} \qquad (5)$$

for aqueous solutions of sodium monofluorophosphate over the concentration range 0.4 to 2.0 molal at 25°C.

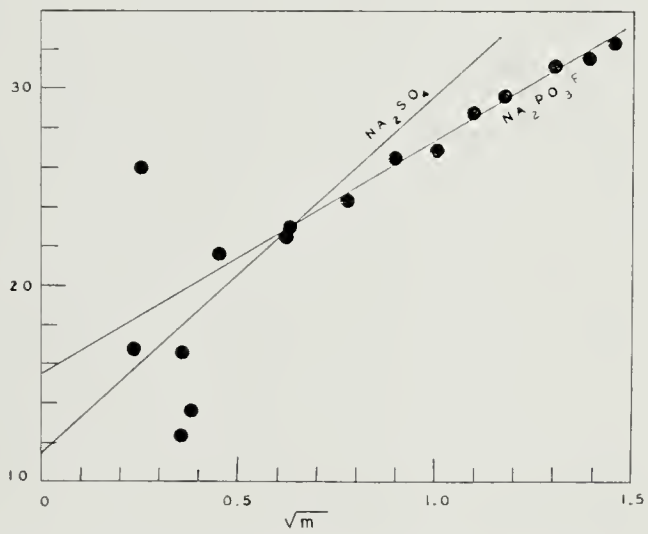

FIGURE 1.—Masson Plot for sodium monofluorophosphate and sodium sulfate at 25°C.

Figure 1 represents the Masson plot of our data with the least-squares line drawn. Included is the line for sodium sulfate taken from the data of Longsworth (1935).

DISCUSSION

As we interpret the extrapolated value of $\varnothing_v^\circ$ of sodium monofluorophosphate, it is valid above 0.4 molal and represents the state of the salt in the region for which we have made density measurements. The limiting value, $\varnothing_v^\circ$, cannot be interpreted as representing the salt

at low solution concentrations because hydolysis changes this parameter as was observed for sodium carbonate by Lamb and Lee (1913). Comparison of $\varnothing_v^\circ$ with that of sodium sulfate verifies the expectation that the monofluorophosphate ion is more extensively hydrated than sulfate. Although both ions are tetrahedral and display crystalline isomorphism, the monofluorophosphate ion is assymmetrical so would be expected to be more extensively hydrated than sulfate in aqueous solution.

The difference in slope of the line for sulfate and monofluorophosphate solutions also reflects the more extensive hydration of monofluorophosphate. At higher concentrations the apparent molal volume of monofluorophosphate is less than sulfate. We might interpret this as a manifestation of the compression of that extra quantity of water which is included in the hydration sphere of the monofluorophosphate ion thus effectively reducing the actual volume occupied by solvent in these solutions.

These simple differences in hydration point out the danger in equating solution properties of sulfate and monofluorophosphate simply because they will form mixed salts and their alkaline-earth salts have similar solubilities. Devonshire and Rowley (1962) have substituted the activity coefficients of sulfuric acid for those of monofluorophosphoric acid, H_2PO_3F, in a study of the hydrolysis of monofluorophosphoric acid. Our observations on molal volumes would indicate the danger in such a rash assumption even without the more obvious inconsistency resulting from wide divergence of the acid dissociation constants themselves. Devonshire (Van Wazer, 1958) has reported approximate values of the dissociation constants of monofluorophosphoric acid which show this acid to be much weaker than sulfuric.

Acknowledgment

The authors are grateful for financial suport from the Cooperative Research Program in Chemistry of the Edwardsville Campus of Southern Illinois University and for the gift of sodium monofluorophosphate from the Ozark-Mahoning Company of Tulsa, Oklahoma.

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NEWS AND COMMENTS

This issue of the Transactions and the one that preceded it were paid for by funds collected from you readers. Some hasty calculations and rounding of figures show that each of you contributed approximately two cents toward the cost of this page.

If you want to publish in haste in the Transactions, write a "Note". Otherwise, you will wait and wait and wait. Volume 58 is full of papers and good start has been made toward filling the first issue for 1966.

In order that you may get your two cents worth from this page, I'll stem my flow of golden words and bring to you a message from the new President of the Illinois Academy of Science—G. R. Yohe of the Illinois State Geological Survey.

At the DeKalb meeting of the Academy there was some discussion in the Council of the desirability of holding our Annual Meeting in the fall, rather than in the spring as is current practice. Cited as one possible advantage was the hope that High School science teachers, who are so busy with student's Exposition projects and arrangements that it is difficult or impossible for them to attend a spring meeting, might get there in the fall. It would help the Council to receive a large volume of members' opinions on this matter. Why not send your views to A. E. Liberta, Secretary, Illinois State University, Normal, or to G. R. Yohe, President, State Geological Survey, Urbana, Illinois? Even if such a change receives a favorable vote, it could not be implemented for some time, as we are committed to meet at Illinois State University in Normal in April of 1966 and at Eastern Illinois University in Charleston in April of 1967.

The Academy could use new members, and many of the scientists in the state could use Academy membership. Our annual meetings bring us interesting and instructive papers as well as fine opportunities to meet our colleagues. And in recent years (I forbid the Editor to change a word of this sentence) the TRANSACTIONS has become an attractive, modern journal of which we are proud, and it is being issued four times a year on schedule. The only way to subscribe to it is to become a member of the Academy, and it's worth the $5.00 and then some. Show a copy to your friends, and ask them to join the Academy. Membership application blanks may be obtained from the Secretary, from the President, or from Dr. Max R. Matteson, 343 Natural History Building, University of Illinois, Urbana, Chairman of the Membership Committee, or from any member of his committee.

—G. R. Yohe

NOTES

GENNAEOCRINUS SP. FROM THE GLEN PARK FORMATION OF NORTHEASTERN MISSOURI

GEORGE H. FRAUNFELTER

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ABSTRACT. — The presence of *Gennaeocrinus* sp. in the Glen Park Formation suggests a Devonian age for that unit.

To my knowledge a specimen of *Gennaeocrinus* collected by me represents the first reported occurrence of this genus in the Glen Park Formation. The collection locality is a road cut along the west side of a gravel road about one-half mile south of Stark Nursery in the SE¼ SE¼ SW¼ sec. 25, T. 54 N., R. 2 W., Pike County, Missouri. The specimen is deposited as University of Missouri No. 14869.

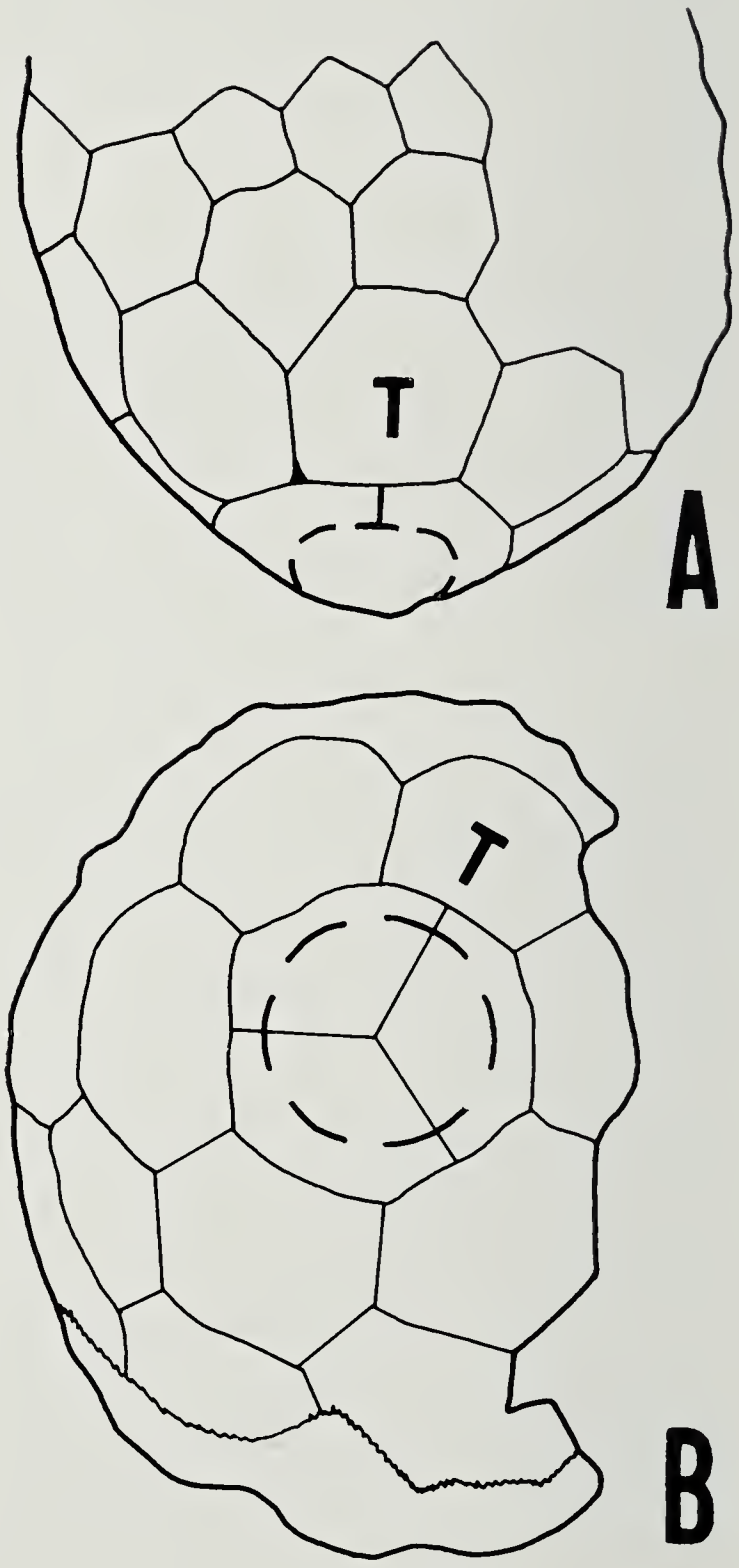

FIGURE 1.—Calyx of *Gennaeocrinus* sp., University of Missouri No. 14869, from the Glen Park Formation near Louisiana, Missouri. (A) Posterior view showing the position of T and associated anal plates, x1, and (B) Basal view showing the position of BB, RR, and T plates, x1.

DESCRIPTION

Calyx medium-sized, incomplete, about 28 mm. in diameter, apparently wider than high, semi-globose, slightly distorted. BB 3, pentagonal, slightly thickened to form rim. RR 5, hexagonal, about as wide as high. T plate narrower than RR, rounded, followed by three plates in the first row (one missing) and five in the second row (two missing). PBrBr 5, hexagonal, much smaller than RR. IBrBr 4, hexagonal, apparently followed by three plates in the second row. PBrBr followed by hexagonal PAxAx of slightly smaller size. Calyx above PAxAx missing or poorly preserved (Fig. 1).

Ornamentation, plates and plate arrangement similar to that of *G. kentuckyensis* (Shumard).

DISCUSSION

Stuart Weller (1906, pp. 435-471) described the Glen Park fauna, consisting largely of pelecypod, brachiopod and gastropod species, the majority of which exhibit strong Devonian affinities. Some of the species, according to Weller, indicate a strong lower Mississippian relationship. It was primarily, however, the presence of fragmentary crinoid remains identified by Weller as *Ac-*

tinocrinus? sp. and *Agaricocrinus*? sp., which led him to assign a Kinderhookian age to the Glen Park Formation.

A later review by Moore (1928, pp. 136-137) listed the same crinoid genera from the Glen Park and confirmed its Kinderhookian age.

In 1938, E. B. Branson (part 1, p. 132) stated: "The fragments figured by Weller and referred questionably to *Actinocrinus* and *Agaricocrinus* are not complete enough to distingush them from Devonian genera." Branson, nevertheless, still considered the Glen Park to be lower Mississippian in age.

Judging by Weller's illustration, some of his crinoid fragments might be referrable to *Gennaeocrinus*. The specimen here described is both complete enough and well enough preserved to be referred to *Gennaeocrinus* with certainty.

In the past the Glen Park Formation has been assigned to the Mississippian. Some geologists, however, have considered it to be Devonian in age (Mehl, 1960, pp. 73-74 and 104). The presence of *Gennaeocrinus* sp., which is considered restricted to Devonian strata, suggests to this author that the Glen Park might more properly be included among Devonian beds.

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Manuscript received February 4, 1965.

A PRELIMINARY CHECK-LIST OF THE AQUATIC HYDROPHILIDAE OF ILLINOIS

DAVID P. WOOLDRIDGE

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Abstract. — A list of species of hydrophilid water beetles known to occur in Illinois is presented.

The following list of the hydrophilid water beetles was made as part of a continuing survey of the aquatic beetles of Illinois. This list includes all species which the author has seen from Illinois or collected personally. The responsibility for all identifications is his. An indication of the known distribution is made for those species which do not appear to occur throughout the state, although complete county by county records must await the results of continuing collecting.

Berosinae

Berosus pugnax LeC.
Southern half of Illinois
B. aculeatus LeC.
B. pantherinus LeC.
B. peregrinus (Hbst.)
B. exiguus (Say)
B. infuscatus LeC.
B. striatus (Say)
B. fraternus LeC.
Derallus altus (LeC.)
Extreme southern Illinois

Hydrophilinae

Hydrophilus triangularis (Say)
Hydrochara obtusata (Say)
Dibolocelus ovatus (G. & H.)
Tropisternus mexicanus mexicanus (Cast.)
Southwestern part of Ill., in counties bordering Mississippi and Illinois Rivers
T. mexicanus striolatus (LeC.)
Southern half of Ill.
T. lateralis nimbatus (Say)
T. glaber (Hbst.)
Extreme northern Illinois
T. blatchleyi modestus d'Orch.
T. natator d'Orch.
T. ellipticus (LeC.)
West central Illinois

Hydrobiinae

Hydrobius fuscipes Linn.
Northern Illinois
Anacaena limbata (Fab.)

Helochares maculicollis Muls.
Southern two-thirds of Illinois
Laccobius agilis Rand.
Crenitis longulus (Fall)
Only Madison Co. records known
Helocombus bifidus (LeC.)
Paracymus despectus (LeC.)
P. subcupreus (Say)
Enochrus pygmaeus (Fab.)
E. ochraceus (Melsh.)
E. perplexus (LeC.)
E. cinctus (Say)
E. horni Leech
E. consortus Green
Southern one-third of state
E. diffusus (LeC.)
Cymbiodyta fimbriata (Melsh.)
C. blanchardi Horn
Northern Illinois
C. minima Notm.
Northern Illinois
C. vindicata Fall
C. acuminata Fall

Chaetarthriinae

Chaetarthria atra (LeC.)

The author would appreciate seeing any specimens of Illinois water beetles and will gladly determine any which are sent to him.

Five other species, known to occur in surrounding states, have been omitted from the list because specimens from Illinois have not yet been seen by the author. These are *Tropisternus mixtus* (LeC.), *Hydrobius tumidus* LeC., *H. melaenum* Germ., *Cymbiodyta rotunda* (Say), and *Chaetarthria pallida* (LeC.).

Hydrochus and *Helophorus* which have often been included in the Hydrophilidae are not treated here, since studies of their larval characters indicate that they should be treated as separate families.

ACKNOWLEDGMENTS

Thanks are due the Illinois Natural History Survey which has been more than generous in the loan of material. Southern Illinois University Graduate Research Grant No. 43-7-21443 has in part supported the necessary travel and collecting expenses.

Manuscript received January 20, 1965.

NOTES ON A POPULATION OF TURBELLARIAN FLATWORMS, *PROCOTYLA FLUVIATILIS* LEIDY

STEVE L. WUNDERLE

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ABSTRACT. — A large population of turbellarian flatworms, *Procotyla fluviatilis* Leidy, was found in Mason City, Mason County, Illinois. The population increased from 245 flatworms on February 16, 1961, to 1,200 specimens on February 15, 1964. The increase may have resulted from a greater food supply and from more protective cover for the flatworms caused by an increase of aquatic vegetation and reduced water velocity.

FIGURE 1.—A 14.5 mm specimen of *Procotyla fluviatilis*. Photograph by Wilmer Zehr, Illinois Natural History Survey, Urbana, Illinois.

Procotyla fluviatilis Leidy, (Fig. 1) is a large white flatworm usually inhabiting lakes, ponds, rivers and springs. It is commonly found on the underside of stones, debris and acquatic vegetation. The distribution of this species includes all of northeastern North America (Kenk, 1944); however, its occurrence in Illinois is relatively unknown. Woodworth (1897) found the species at Thompson's Lake (now drained) in Mason County near Havana, Illinois, and Hyman (1928) recorded it at Cary, McHenry County, Illinois. The species has never been reported in large numbers.

The population of flatworms discussed in this paper, was found in a spring-fed drainage ditch (average yearly temperature, 12.3 C) located in Sec. 29, 30,

31, T 19.5N, R 5.5W, Mason City Township, Mason County, Mason City, Illinois 20 miles southeast of Havana, Illinois. The ditch flows for one-fifth of a mile parallel to, and on the south side of an east-west gravel road; it then flows in a southwesterly direction for 1.6 miles before emptying into Salt Creek.

On February 16, 1961, the entire ditch was searched for flatworms; 245 specimens of *P. fluviatilis* were found in the east-west part of the ditch. None was found in the part of the ditch flowing southwest. In much of the east-west section of the ditch the rate of water flow was 1.45 cubic feet per second. The rate of flow increased gradually to a velocity of 7.46 cubic feet per second at the point where the ditch emptied into Salt Creek. There was little aquatic vegetation in the ditch at that time. Flatworms were found under the following debris: the top of a chicken feeder, an auto tire, pieces of brick and tile, small boards, and dead tree twigs and branches. Some specimens were observed moving on the bottom of the ditch.

On February 15, 1964, the ditch was searched again for flatworms. Aquatic vegetation consisting of *Lemna minor, Ceratophyllum demersum, Bidens comosa, B. cernua, B. coronata,* and *Polygonum fluitans* had increased to such an extent by February, 1964, that little open water occurred in the portion of the ditch along the east-west road (Plant nomenclature, Jones, 1950). The remainder of the ditch, the portion running southwesterly, was completely covered with *Nasturtium officinale.* No water flow was measured for 1964.

Approximately 1,150 specimens were found in the part of the ditch flowing west along the road. Eight hundred seventy-five of these specimens were under debris as in 1961, while 275 were found on the under-side of aquatic vegetation. Fifty individual specimens were observed under debris in the section of the ditch flowing in a southwesterly direction 10 yards south of the east-west gravel road; none was found farther downstream.

The apparent increase in numbers of flatworms from 1961 to 1964, and extension of the population into the south ditch may have resulted from an increase in its unique food supply of small crustacea, an increase in acquatic vegetation, and reduced water velocity which offered more protective cover for the flatworms.

This study, done while attending Eastern Illinois University, was under the supervision of Dr. Hugh Rawls, Associate Professor of Zoology.

Literature Cited

Hyman, L. H. 1928. Studies on the morphology, taxonomy, and distribution of North American triclad Turbellaria. 1. *Procotyla fulviatilis.* Commonly but erroneously known as *Dendrocoelum lacteum.* Trans. Amer. Microscop. Soc., 47:222-255.

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Woodworth, W. McM. 1897. Contributions to the morphology of the Turbellaria. II. On some Turbellaria from Illinois. Bull. Mus. Comp. Zool., 31:1-16.

Manuscript received January 13, 1965.

THE VISCOSITY OF AQUEOUS SOLUTIONS OF SODIUM MONOFLUOROPHOSPHATE

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E. St. Louis

ABSTRACT. — The viscosity of aqueous solutions of sodium monofluorophosphate, Na_2PO_3F, has been determined at 25° C over a concentration range up to 1.6 molar. The concentration dependence of the fluidity, φ, can be expressed by the equation $\varphi = 1 - 0.01568\sqrt{c} - 0.4160c$ up to a concentration of 0.5 molar.

We have determined the viscosity of aqueous solutions of sodium monofluorophosphate, Na_2PO_3F, at 25° C over the concentration range 0.014 to 1.6 moles per liter. Viscosity measurements were made in quadruplicate in modified Ostwald viscosimeters. Solutions were prepared from crystalline sodium monofluorophosphate of 97.0% purity.

TABLE 1. — Relative Viscosity as a Function of Molar Concentration for Aqueous Solutions of Sodium Monofluorophosphate at 25° C.

c, moles l^{-1}	η
0.0140	1.0024
0.0207	1.0041
0.0336	1.0141
0.0433	1.0167
0.0511	1.0210
0.0552	1.0270
0.0640	1.0317
0.0792	1.0387
0.0872	1.0395
0.0948	1.0445
0.1129	1.0560
0.1957	1.0963
0.2928	1.1509
0.3773	1.2009
0.4075	1.2163
0.6098	1.3452
0.7207	1.4177
0.8438	1.5229
1.0655	1.7095
1.2296	1.8657
1.3448	1.9754
1.6374	2.9051

Our data are presented in Table 1 where c represents the concentration of sodium monofluorophosphate in moles per liter and η is the relative viscosity of the solutions. Relative viscosity is the ratio of the viscosity of the solution to that of the pure solvent.

The data was evaluated according to the methods of Grűneisen (Harned and Owen, 1950) and Jones and Dole (1929). Grűneisen observed that in regions of high dilution viscosity is not a linear function of concentration. Plotting relative viscosity versus concentration, he observed that the curves for many electrolytes exhibit negative curvature as concentration is reduced. This behaviour for electrolytes appears to be general and has been termed (Jones and Talley, 1933) the Grűneisen effect. Our data for sodium monofluorophosphate exhibits this general behaviour.

Jones and Dole (1929) observed that the equation

$$\varphi = 1 + A\sqrt{c} + Bc \qquad (1)$$

accurately represents the fluidities, φ, of many solutions to reasonably high concentrations. Fluidity is defined as the reciprocal of the relative viscosity. The data were plotted as $(\varphi - 1)/\sqrt{c}$ versus $\sqrt{c}$ as a consequence of Equation 1 being rearranged to

$$(\varphi - 1)/\sqrt{c} = A + B\sqrt{c} \qquad (2)$$

which is the equation of a straight line. The resulting plot yielded negative values of A and B. This behaviour is generally observed for electrolytes which increase the viscosity of the medium. Our data were linear up to a concentration of 0.5 moles per liter. A least-squares analysis of the data yields the equation

$$\varphi = 1 - 0.01568\sqrt{c} - 0.4160c \qquad (3)$$

for aqueous solutions of sodium monofluorophosphate at 25° C up to a concentration of 0.5 moles per liter.

This work was supported by the Cooperative Research Program in Chemistry of the Edwardsville Campus of Southern Illinois University. The sample of sodium monofluorophosphate used

in this investigation was a gift of the Ozark-Mahoning Company of Tulsa, Oklahoma.

Literature Cited

Harned, H. S., and B. B. Owen. 1950. The Physical Chemistry of Electrolytic Soltuions. Reinhold, New York. 172-178pp.

Jones, G. and M. Dole. 1929. The Viscosity of Aqueous Solutions of Strong Electrolytes with Special Reference to Barium Chloride. J. Am. Chem. Soc. 51:2950.

Jones, G., and S. K. Talley. 1933. The Viscosity of Aqueous Solutions as a Function of the Concentration. J. Am. Chem. Soc. 55:624.

Manuscript received April 29, 1965.

ACADEMY BUSINESS

SECRETARY'S REPORT FOR THE YEAR— APRIL 27, 1963—APRIL 27, 1964

COUNCIL MEETINGS

The Council held four meetings during the year, as stipulated in the Constitution.

First Council Meeting.—The first Council meeting was held in the Missouri Room, Memorial Center, Southern Illinois University on Saturday morning, April 27, 1963, with Presdent Elnore Stoldt presiding. Twelve persons were present.

Dr. E. H. Hadley, Second Vice-President, reported that 208 persons had registered for the 56th Annual Meeting.

Dr. E. C. Galbreath was reappointed Editor of the TRANSACTIONS.

Mr. Arthur R. Wildhagen was reappointed as the Academy's Publicity Advisor.

Miss Joan Hunter was appointed as the Delegate to the AAAS Academy Conference.

Dr. W. B. Hendrickson was appointed as the Historian of the Academy.

Drs. William Lewis and Boris Musulin were appointed to the Audit Committee.

Second Council Meeting.—This was held in the Conference Room of the Illinois State Museum, Springfield, Illinois on Saturday, November 2, 1963. Forty-three members were in attendance.

The first hour of the meeting was devoted to a discussion of Junior Academy reports and problems, after which the Junior Academy officers withdrew to a separate meeting room.

Dr. Galbreath, Editor, reported that a "News and Notes" section had been added to the Transactions and that an abstract would be included at the beginning of each article.

Third Council Meeting. — This was held in the Memorial Union Building, Illinois Wesleyan University, Bloomington on February 8, 1964. Twenty-three members were in attendance.

Dr. Joseph Collins, Second Vice-President, reported that all physical facilities at Illinois Wesleyan University have been reserved for the 57th Annual Meeting.

It was decided that a time and place be included in the Program for members interested in establishing new Sections of the Academy. The time for this meeting will run concurrently with the Paper Sessions and the Secretary will be present at that meeting.

The Section Chairmen presented brief reports regarding the number of papers scheduled for each section.

Dr. R. Evers presented the report of the Planning Committee. The topics discussed by the committee and their actions are summarized below:

1. Suitability of the name Transactions: unanimously voted to retain the name.
2. Establishment of emeritus membership: not recommended.
3. Creating the rank of Fellow: not approved.
4. Permitting equipment manufacturers to exhibit at Annual Meetings: recommended.
5. Recommended the appointment of an Ad Hoc committee to study the possibility of a different time for the annual meeting.
6. Page charge for non-members: tabled.

It was decided that a page charge be instituted for the publication of papers by non-members in the Transactions. The amount to be charged will be determined by the Editor in conference with the Editorial Board and the Librarian, and that these charges can be waived in those cases where the paper has been invited by the Council or by the Editor.

Fourth Council Meeting.—This meeting was called to order at 7:30 P.M. by President Elnore Stoldt following a dinner in the Memorial Union, Illinois Wesleyan University, Bloomington on April 23, 1964. Twenty-six members were present.

The Section Chairmen reported that all preparations for the annual meeting had been completed.

The Secretary read a letter from the Audit Committee stating that the books of the Treasurer had been audited and found to be in order.

THE 57th ANNUAL MEETINGS

General Meeting.—The general session of Friday morning, April 24, 1964, held in the Auditorium of the University Union was called to order by President Elnore Stoldt.

Dr. Lloyd M. Bertholf, President, Illinois Wesleyan University, gave the address of welcome. This was followed by Miss Stoldt's Presidential address, "What Instrument do you Play?"

The Presidential address was followed by a panel discussion, "Answers to Questions." The panel consisted of Dr. Harlow B. Mills, Chief, Illinois Natural History Survey, Dr. C. L. Kanatzar, Dean of the Faculty, MacMurray College, Dr. Robert A. Evers, Associate Botanist, Illinois Natural History Survey, and Dr. Walter B. Welch, Chairman, Department of Botany, Southern Illinois University.

Section Meetings.—On Friday afternoon, April 24, the following papers were presented:

Anthropology

Room 120, Sheriff Hall

Charles H. Lange, Chairman

Southern Illinois University, Carbondale

Culture, Behavior and the Individual. Thorne Deuel, Illinois State Museum, Springfield.

Age and Size Determinations of Fish Remains Collected from Archaeological Sites. Andreas A. Paloumpis, Illinois State University, Normal.

Aquatic Biology

Room 206, Shaw Hall

Maurice Whitacre, Chairman

Illinois Department of Conservation, Carbondale

The Comparative Effects of Parrot Fish Thyroid Gland and Synthetic Thyroxin on the Respiratory Metabolism of White Mice. R. A. Kenner, R. G. Bjorklund and E. C. Gasdorf, Bradley University, Peoria.

Variations in the Carrying Capacity of Ridge Lake for Fish during a Twenty-two-year period. George W. Bennett, Illinois Natural History Survey, Urbana.

Summary of the Age and Rate of Growth of Game Fish in Reelfoot Lake, Tennessee, from 1937 through 1961. Robert J. Shaffman, Spaulding Institute, Peoria.

The Effect of Rotenone on Oxygen Uptake by Bluegill Liver Mitchondria. Robert G. Hiltibran and Michael G. Johnson, Illinois Natural History Survey, Urbana.

Temperature and Salinity Tolerance in *Tilapia*. H. H. Shoemaker and David Thomas, University of Illinois, Urbana.

Hypothetical Additions to the List of Illinois Fishes. Philip W. Smith and Marvin E. Braasch, Illinois Natural History Survey, Urbana.

Botany

Section A

Faculty Lounge, University Union

Kenneth H. Harmet, Chairman

Northern Illinois University, DeKalb

The Stamen in *Erica* and in the Ericaceae in General. Barbara F. Palser, University of Chicago, Chicago.

Some Aspects of Flower Development in *Collinsia heterophylla*. Gould Frederick Schrock, University of Chicago, Chicago.

Effect of Photoperiod on Aging Process: Determination of the Minimum number of Days to Induce Photoinductive Senescence. Donald T. Krizek and Wayne J. McIlrath, University of Chicago, Chicago.

Mass Culture of Bryophyte Tissue. Paul D. Voth, M. J. Schneider, and R. F. Troxler, University of Chicago, Chicago.

Patterns of Cell Death in Elongating Corn Stalks. A. J. Pappelis and Judith Williams, Southern Illinois University, Carbondale.

An Analysis of Growth in the Regenerating Root Apex of *Vicia faba*. John R. Yaeger, University of Chicago, Chicago.

Early History of the Botany Section of the Illinois State Academy of Science. Walter B. Hendrickson, MacMurray College, Jacksonville.

Reactions of Chromogenic Bacteria to Gibberellic Acid. Sister Mary Cecilia Bodman, Mundelein College, Chicago.

Homocysteine Transmethylast from Jack Bean Meal: Partial Purification and Characterization. Lila Abrahamson, University of Chicago, Chicago.

The Effects of Auxins on the Growth and Development of Gemmalings of *Marchantia polymorpha*. Nicholas C. Maravolo, University of Chicago, Chicago.

Section B

Browsing Room, University Union

Robert W. Tuveson, Presiding

University of Chicago, Chicago

Trelease Woods: Woody Vegetation

and Changes in Stand Composition. William R. Boggess, University of Illinois, Urbana.

Effects of Past Agricultural Practices on the Growth and Chemical Content of planted Sycamore. A. R. Gilmore, University of Illinois, Dixon Springs Experiment Station, Simpson, Illinois.

Old-Field Succession in Ogle County, Illinois. Robert A. Bullington, Northern Illinois University, DeKalb, Illinois.

Distribution of *Digitaria sanquinalis* in the Southern Hemisphere. John E. Ebinger, Eastern Illinois University, Charleston.

Further Observations on Hyphal Tips Isolated from Heterocaryons in *Cephalosporium mycophilum*. Robert W. Tuveson, University of Chicago, Chicago.

Early History of the Illinois Academy. Walter B. Hendrickson, MacMurray College, Jacksonville.

The Synnema as a Taxonomic Criterion. Everett F. Morris, Western Illinois University, Macomb.

Plankton Studies of Lake Michigan. III. Annual and Seasonal Periodicity of Lake Michigan Plankton at Milwaukee, Wisconsin. Kenneth E. Damann, Eastern Illinois University, Charleston.

Effects of Plating Densities and Supplementation on Random Ascospore Analyses of *Asperqillus rugulosus*. Darwin O. Coy, University of Chicago, Chicago.

Chemistry

Room 310, Sherff Hall

Bruce Campbell, Jr., Chairman

MacMurray College, Jacksonville

Infrared Absorption Spectra of Beta-Alanine and Some Transition Metal Complexes, Sister Mary Mariana Kennelly, B.V.M., Mundelein College, Chicago.

The Partial Molal Volume of Na_2PO_3F. David G. Rands and James R. Lyerla, Jr., Southern Illinois University, East St. Louis.

Activity Coefficients of Aqueous Solutions of Na_2PO_3F. David G. Rands and A. J. Mogenis, Southern Illinois University, East St. Louis.

Reactions of Some 4-O-Substituted Hexoses with Amine Salts, Marinus P. Bardolph, Northern Regional Research Laboratory, Peoria and Southern Illinois University, Edwardsville Campus, Alton.

Conductivity of Iodine-Dimethylsulfoxide Solutions, Thomas Earl Hanson and Boris Musulin, Southern Illinois University, Carbondale and Theoretical Chemistry Institute, University of Wisconsin, Madison, Wisconsin.

Quantitative Approaches to Association via Additive Properties, Boris Musulin, Theoretical Chemistry Institute, University of Wisconsin, Madison, Wisconsin.

An Inexpensive High-Frequency Titrimeter. R. E. Van Atta and S. T. Mayne, Southern Illinois University, Carbondale, Illinois.

Conservation

Green Room, University Union

Donald T. Ries, Chairman

Illinois State University, Normal

Some Views on Public Holdings. Willard D. Klimstra, Southern Illinois University, Carbondale.

Wood Duck Houses and Raccoon Predation. Randy Eaton and J. Henry Sather, Western Illinois University, Macomb.

Geography

Room 7, Old Science Building

Charles Alexander, Chairman

University of Illinois, Urbana

"Population Change in Selected Villages of the Grand Prairie." Neil E. Salisbury, State University of Iowa, Iowa City, Iowa.

"Social Activities in Selected Middle Western Villages." John Fraser Hart, Indiana University, Bloomington, Indiana.

"The Urbanization of the Open Country; Population Changes and Convergence of Life Styles." Everett G. Smith, Jr., University of Illinois, Urbana.

"The Location of the Man-Made Fibers Industry." David W. Icenogle, University of Illinois, Urbana.

"The Siltation and Evaporation of Lake Charleston." Ying Cheng Kiang, Eastern Illinois University, Charleston.

"Factors Affecting Land Values in Wabash County, Illinois." Nelson R. Nunnally, University of Illinois, Urbana.

Geology

Room 204, Shaw Hall

T. K. Searight, Chairman

Illinois State University, Normal

Middle, Late, and Post-Pennsylvania Folding of the LaSalle Anticlinal Belt and Adjacent Structures in East Central Illinois by Kenneth E. Clegg, Illinois State Geological Survey.

Concerning Cross Sections by Allen Keller, Western Illinois University, Urbana.

X-Ray Spectrographic Analysis of Two

Weathering Profiles from East Central Illinois by W. Hilton Johnson, University of Illinois, Urbana.

Structural and Textural Characteristics of a Pennsylvanian Shale and Its Joint Fillings by W. Arthur White, Illinois State Geological Survey.

Glacial Lake Watseka, by George E. Ekblaw, Illinois State Geological Survey.

The Excavation and Geologic Setting of the Perry Mastodon near Glen Ellyn, Illinois, by Douglas Block, Wheaton College, Wheaton.

Mastodon Tusks from Illinoisan Outwash Jersey County, Illinois, by Dorothy Gore, Principia College.

Meteorology and Climatology

Room 108, Sherff Hall

Dorothy L. Bradbury, Chairman

University of Chicago, Chicago

Argonne's Expanded Soil Climatology Program. James E. Carson, Argonne National Laboratory, Argonne.

Climatology of Low Level Wind Maxima. William D. Bonner, The University of Chicago, Chicago.

On the Velocity of Mean Autumn 300-mb Winds Associated with the Jet Stream over North America. James D. Lahey, Northern Illinois University, DeKalb.

Results of a Detailed Field Investigation of a Central Illinois Hailstorm. Stanley A. Changnon, Jr., and Glenn E. Stout, Illinois State Water Survey, Urbana.

On the Operational Use of the WSR—57 Radar. George Polensky, Chicago District Forecast Center, U.S. Weather Bureau, Chicago.

Freak Winter Snowstorms in Illinois. Stanley A. Changnon, Jr., Illinois State Water Survey, Urbana.

A Study of Clouds with the Use of U-2 Photographs. Dorothy L. Bradbury, The University of Chicago, Chicago.

New Developments in USAF Electronic Meteorological Equipment. Charles Hooper, USAF, Chanute AFB, Rantoul.

Microbiology

Room 103, Shaw Hall

K. C. Atwood, Chairman

University of Illinois, Urbana

Crambe: Susceptibility to Some Plant Viruses. H. H. Thornberry and Mary Ruth Phillippe, Dept. of Plant Pathology, University of Illinois, Urbana.

Orchid Blossom Necrosis: Susceptibility of Non-Orchid Plants to Viruses Associated with the Disease. R. B. Owen, Mary R. Phillippe and H. Thornberry, Dept. of Plant Pathology, University of Illinois, Urbana.

Orchid Blossom Necrosis: Detection of Associated Viral Particles by Electron Microscopy. Mary R. Phillippe, J. Brandes and H. H. Thornberry, Dept. of Plant Pathology, University of Illinois, Urbana.

Physics

Room 226, Holmes Hall

Richard F. Watson, Chairman

Southern Illinois University, Carbondale

Acceleration of Small Metal Pellets by Pulsed Magnetic Fields. Robert David Joseph, Greenville College, Greenville.

Important Steps in the Processing of Thick Emulsions. O. B. Young and Robert Woll, Southern Illinois University, Carbondale, and Argonne National Laboratory.

Gamma-ray Studies of Radon Daughter Activity in Rain Water. Harold Belt, Southern Illinois University, Carbondale.

Conductivity and Thermal Emf in Indium Oxide. Gerald Swanson, Southern Illinois University, Carbondale.

Mahlon Loomis, American Discoverer of Radio in 1866, Report No. 2. O. B. Young, Southern Illinois University, Carbondale.

Science Teaching

Room 205, Shaw Hall

H. O. Jackson, Chairman

Illinois State University, Normal

A Psychosocial Look at the Underachieving and/or Disinterested Student of Science and Mathematics.

A Complete Gas Laws Demonstration Apparatus. Calvin P. Midgley, Mundelein College.

Experiences with Large Groups and Team Teaching in Biology. George R. Abraham, Lincoln-Way Community High School, New Lenox.

Zoology

Section A

Room 305, Sherff Hall

John D. Anderson, Chairman

University of Illinois, Urbana

ATP and Radiation Induced Dominant Lethals. Sidney Mittler and Mary Webster, Dept. of Biological Sciences, Northern Illinois University, DeKalb, Illinois.

DDT Resistance of *Drosophila melanogaster* Miegen after Relaxation of

Selection. Irene Y. L. Wei and Jack Bennett, Department of Biology, Northern Illinois University, DeKalb, Illinois.

A Study of Post-Embryonic Development in an Acarid Mite (Acarina: Acaridiae). Ward L. Miller, Jr. and Charles J. Rohde, Jr., Dept of Biology, Northern Illinois University, DeKalb, Illinois.

Immunological Study of a Pair of Fraternal Twin Chickens. Jack Bennett, Dept. of Biology, Northern Illinois University, DeKalb, Illinois.

Distribution of Sulfhydryl groups in Development. Lester C. Shell and Denzil J. Hawes-Davis, Dept. of Biology, Millikin University, Decatur, Illinois.

The Effect of Starvation on the Coelomocytes of the Holothurian, *Cucumaria miniata*. Howard R. Hetzel, Dept. of Zoology, Illinois State University, Normal, Illinois.

Cytochemical Studies on *Trichomonas tenax*. Wayne W. Wantland, Division of Science, Illinois Wesleyan University, Bloomington, Illinois.

Genetic Observations on a Glaucoma-Like Condition in the Rabbit. Edward J. Bauer, Jr. and Jack Bennett, Dept. of Biology, Northern Illinois University, DeKalb, Illinois.

Motive Force in Myxomycete Plasmodia. Donald M. Miller, Dept. of Physiology and Biophysics, University of Illinois, Urbana, Illinois.

Uptake and Distribution of K^{42} in the Plasmodium of a Myxomycete. John D. Anderson, Dept. of Physiology and Biophysics, University of Illinois, Urbana, Illinois.

Section B

Room 311, Sherff Hall

Donald M. Miller, Presiding

University of Illinois, Urbana

Incidence of Oral Protozoa in a Central Illinois Community. Wayne W. Wantland and John Connolly, Division of Science, Illinois Wesleyan University Bloomington, Illinois.

Silver Impregnation of the Enigmatic Holotrich Ciliate *Cyathodinium piriforme*. Jerome J. Paulin, Dept. of Zoology, University of Illinois, Urbana, Illinois.

Male Genitalia in the Genus *Spheconyia* (Diptera; Fam. Syrphidae). Kenneth Weisman and Y. Sedman, Dept. of Biology, Western Illinois University, Macomb, Illinois.

Preliminary Observations of the Behavior of the Isopod, *Asellus militaris*. Howard R. Hetzel, Dept. of Zoology, Illinois State University, Normal, Illinois.

Studies in Chicken Behavior. Karen L. Hagen and Jack Bennett, Dept. of Biology, Northern Illinois University, DeKalb, Illinois.

Serial Sections from Plastic-Embedded Specimens. Charles J. Rohde, Jr., Dept. of Biological Sciences, Northern Illinois University, DeKalb, Illinois.

Progress Report: An Ecological Study of an Illinois River Heronry. Richard G. Bjorklund, Dept. of Biology, Bradley University, Peoria, Illinois.

The Microcommunity of *Acrobasis rubrifasciella* Pack. on *Alnus* at Ely, Minnesota. Walter V. Balduf, Dept. of Entomology, University of Illinois, Urbana, Illinois.

The Distribution of the Flies of the Genus *Chrysogaster* (Diptera; Fam. Syrphidae). Yale S. Sedman, Dept. of Biology, Western Illinois University, Macomb, Illniois.

Competition Between Various Attached X Stocks in Laboratory Population Cages. Marion S. Baran and Sidney Mittler, Dept. of Biological Sciences, Northern Illinois University, DeKalb, Illinois.

A Linkage Relationship in *Drosophila immigrans* Sturtevant. Jack C. Saichek and Jack Bennett, Roosevelt Jr. High, Rockford, Illinois and Dept. of Biology, Northern Illinois University, DeKalb, Illinois.

THE ANNUAL BUSINESS MEETING

The Business Meeting was called to order at 5:00 P.M., April 24, 1964, in the new Science Building, Illinois Wesleyan University, Bloomington, Illinois by President Elnore Stoldt. About 60 members were in attendance.

Reports of Officers.—Secretary Paloumpis reported items which are recorded in the foregoing reports of the Council meetings. Treasurer Klimstra's report is published herewith. This report was accepted by passage of a motion by Dr. Klimstra and seconded by Dr. Kaplan.

Reports of Standing Committees.—Dr. Ekblaw, Chairman of the Affiliations Committee, reported on the proposed institutional membership in the Illinois Society for Medical Research. It was the opinion of the committee that we should lend support to the organization, but should not enter into an affiliation with the organization. The Secretary was instructed to write the Secretary of the Illinois Society for Medical Research and inform them of this action.

Dr. Miller, Chairman of the Research Grants Committee recommended that the following grants be awarded:

Dr. Roger Ulrich—$300.00. Illinois Wesleyan University, Conditioning Chamber for study of subcortical stimulation in psychology departmental research.

Mr. William H. Hill—$150.00. Illinois State University. Cost of field trip to collect Texas Pleistocene snakes. Dr. J. Alan Holman, Sponsor.

Dr. Dale E. Birkenholz—$114.00. Illinois State University. Study of harvest mouse in Central Illinois.

Dr. John J. Spokas—$200.00. St. Procopius College. To purchase two solid state surface barrier detectors to be used in student research.

Dr. Howard R. Hetzel—$100.00. Illinois State University. Support of continuing study of holothurian coelomocytes.

A motion for the approval of these grants was made by Dr. Ekblaw, seconded by Dr. Evers, and passed.

Reports of Special Committees.—The Resolutions Committee (Dr. C. L. Kanatzar, Chairman) submitted the following resolutions; all were approved by the Academy:

1. APPRECIATION TO THE HOST—*Whereas* many members of the Administration, Faculty and Staff of Illinois Wesleyan University have been responsible for the arrangements essential to the Fifty-seventh Annual Meeting of the Illinois State Academy of Science, *Be it resolved* that the Academy express its gratitude to all who have participated in any way in arranging this Annual Meeting and especially to

   Dr. Lloyd M. Bertholf, President of the University

   Dr. Joseph C. Collins, Second Vice-President of the Academy, in charge of local arrangements, and

   Dr. Wayne W. Wantland, Chairman of the Division of Natural Sciences of the University

   Be it further resolved that the Secretary be directed to send copies of this resolution to those specifically named.

2. APPRECIATION OF SERVICE—*Whereas* responsibility has been accepted by Dr. J. Louis Martens, Department of Biological Sciences, Illinois State University, for arranging the Botany Field Trip, and by Dr. Thomas Searight, Department of Geology, Illinois State University, for arranging the Geology Field Trip, which constitute a significant portion of the program for the Fifty-seventh Annual Meeting of the Academy, *Be it resolved* that the Academy express its thanks to Drs. Martens and Searight for organizing and conducting these field trips, *Be it further resolved* that the Secretary be directed to send copies of this resolution to them.

3. ILLINOIS NATURE PRESERVE COMMISSION — *Whereas* Governor Otto Kerner has signed H.B. 1538 which permits the acquisition, control, maintenance, improvement and protection of State parks and nature preserves, and *Whereas* he has signed H.B. 1539 establishing the Illinois Nature Preserves Commission which formulates policies providing for continued preservation of such areas without unreasonable impairment, thereby providing optimal habitats for plant and animal species as well as benefits of an enduring resource of natural land, *Be it resolved* that the Illinois State Academy of Science express its appreciation to the Governor for his interest and leadership in the establishment and implementation of these bills, and *Be it further resolved* that the Secretary of the Academy be directed to send copies of this resolution to the Governor and to the Director of the Department of Conservation.

4. RADIO DISCOVERY COMMITTEE—*Whereas* October 1966 will mark the 100th Anniversary of the experimentation by Mahlon Loomis dealing with the transmission of intelligible signals through space, and *Whereas* it is possible that this may represent the earliest work of its kind leading to the discovery of the principle of radio, and *Whereas* the Radio Discovery Committee appointed by the Illinois State Academy of Science has undertaken considerable research upon this subject to attempt to determine the founder of the principle of radio, *Be it resolved* that the Academy strongly urge that further serious investigation be conducted in the history of the discovery of radio in order that any confusion as to the founder of the principle of radio may be clarified and appropriate credit bestowed in the literature dealing with the subject.

5. MINIMUM STANDARDS OF PREPARATION FOR TEACHERS OF CHEMISTRY, PHYSICS, AND PHYS-

ICAL SCIENCE — *Whereas* rapid changes have occurred in Chemistry and Physics, which have brought about the great necessity for more study of content material in these sciences, *Be it resolved* that the following revisions be made in the Minimum Standards of Teacher Preparation, prepared by the Supervisory and Certification Departments, Office of the Superintendent of Public Instruction, State of Illinois:

Recommended Minimum Preparation for the Teacher of Chemistry, Physics, and Physical Science in Recognized Illinois High Schools.

Chemistry, twenty-four (24) semester hours

The minimum preparation for teaching chemistry must include at least:

1. Sixteen (16) semester hours of chemistry with a minimum of eight (8) hours of course work with laboratory.
2. Eight (8) semester hours of physics with laboratory.

It is recommended that a teacher of chemistry have minimum preparation as a teacher of mathematics.

Physics, twenty-four (24) semester hours

The minimum preparation for teaching physics must include at least:

1. Sixteen (16) semester hours of physics with a minimum of eight (8)hours of course work with laboratory.
2. Physics courses taken beyond the first year must have calculus as a prerequisite or it may be taken concurrently.
3. Eight (8) semester hours of chemistry with laboratory. It is recommended that a teacher of physics have minimum preparation as a teacher of mathematics.

Physical Science, twenty-four (24) semester hours in the field with the following minimum preparation in each subject area taught:

A. Introductory Physical Science, sixteen (16) semester hours. The minimum preparation for the teaching of introductory physical science must include at least:
   1. Not less than eight (8) semester hours of work in chemistry with laboratory.
   2. Not less than eight (8) semester hours of work in physics with laboratory.
   3. The remaining eight (8) semester hours may be chosen from the subject areas of Chemistry, Physics, Astronomy, Meteorology, Physiography and Geology.

B. Advanced Physical Science, twenty-four (24) semester hours. The minimum preparation for the teaching of advanced physical science must include at least:
   1. Not less than twelve (12) semester hours of work in chemistry with laboratory.
   2. Not less than twelve (12) semester hours of work in physics with laboratory.
   3. It is recommended that additional hours be chosen from astronomy and geology.

C. Astronomy, five (5) semester hours. The remaining nineteen (19) semester hours must be in chemistry, physics, meteorology and geology.

D. Physiography, five (5) semester hours.
   The remaining nineteen (19) semester hours must be in chemistry, physics, meteorology and geology.

E. Geology, eight (8) semester hours. The remaining sixteen (16) semester hours must be in chemistry, physics, astronomy, meteorology and physiography.

Be it further resolved that the Secretary of the Academy be directed to send a copy of this resolution to Mr. Ray Page, Superintendent of Public Instruction of the State of Illinois. *Be it further resolved* that the Illinois State Academy of Science strongly urge a meeting of the Superintendent of Public Instruction of the State of Illinois with the various professional organizations for teachers in these fields whereby the recommendations stated above may be considered for action; and *Be it again further resolved* that the Secretary of the Academy be directed to send a copy of this resolution to Mr. Ray Page, Superintendent of Public Instruction.

6. Necrology—*Whereas* during the past year the Academy has lost by death one member, Dr. Charles A. Shull, Asheville, North Carolina, *Be it resolved* that the Academy give expression to its sorrow for his death by rising for a moment of silence.

Old Business—The Secretary read the following recommended changes in the Constitution:

Article III—Membership and Dues
Section 3: Should be changed to: Any college or high school student who is certified by an advisor or instructor may become a Student Member with all rights and privileges of membership except that of voting and holding office. The student membership shall apply to graduate students until the termination of their student status but shall not extend beyond five years after the completion of the bachelor's degree.

Article III—Membership and Dues
Section 4—(New Section) Emeritus membership is open to those persons who are retired from their professional duties, on permanent sick leave, or other such unavoidable types of discontinuance of their profession. The persons should have been members of the Academy for at least ten (10) years before consideration for the eligibility of their emeritus status. The annual dues for emeritus membership shall be $1.00.

New Business.—The Secretary read the following recommended change in the By-Laws:

Article II—Committees and Delegates
Section 1—Teacher Training Committee be changed to the Committee for Science Teaching.

Andreas A. Paloumpis,
Secretary

TREASURER'S REPORT—
JANUARY 1, 1963—DECEMBER 31, 1963

BALANCE CARRIED FORWARD, January 1, 1962			$10,237.15
TOTAL RECEIPTS			
Dues			
Regular		$ 2,736.41	
Life		100.00	
Sustaining & Patron		5,140.00	
Registration		103.50	
A.A.A.S. Research Grants		864.00	
Interest, U.S. Bonds		106.90	
Interest, Savings & Loan		270.00	
Sale of publications		103.52	
Jr. Academy School Registration		2,058.22	
			$11,482.55
			$21,719.70
TOTAL EXPENDITURES			
Regular Academy			
Council		$ 189.49	
Secretary's Office		790.17	
Treasurer's Office		661.36	
Editor's Office		471.75	
Librarian		804.96	
A.A.A.S. Research Grants		864.00	
Honoraria		350.00	
Membership Committee		30.00	
Miscellaneous		30.40	
Jr. Academy			
General (1962-1963)	$ 4,822.59		
S.T.S. (1962-1963)	275.63	5,098.22	9,290.35
TOTAL			$ 9,290.35
Junior Academy of Science			
State Chairman's Office			
Stenographic		$ 826.00	
Travel		433.97	
Hire of Sub. Teacher		262.69	
Postage		400.00	
Telephone & Telegraph		121.40	
Stationery & Mat		390.76	
State Chairman Elect		100.00	
State Paper Sessions		200.00	
State Judging Expenses		18.33	
Speaker		199.75	
			$ 2,952.90

Publications and Printing		
1963 Yearbook	$ 107.53	
Handbook	163.50	
Newsletters	52.00	
Pamphlets	105.00	
Photography	49.52	
Award Certificates	46.45	
		$ 524.00
TOTAL		$12,767.25
Outstanding Checks in 1962 cashed in 1963		$ 33.00
Outstanding Checks for 1963		—3,788.78
TOTAL ACTUAL EXPENDITURES		$ 9,011.47
Cash in Carbondale National Bank, December 31, 1963		$12,708.23
OTHER ASSETS		
Permanent Fund (U.S. Bonds)	$ 1,700.00	
		$ 1,700.00
Reserve Funds		
U.S. Bonds	$ 1,800.00	
State Savings & Loan	6,000.00	
		$ 7,800.00
Frank Reed Memorial Fund		
Balance Carried Forward Jan. 1, 1962	$ 1,178.09	
Interest	47.59	
		$ 1,225.68
TOTAL OTHER ASSETS		$10,725.68
Total Assets of Academy, December 31, 1963		
Cash in Carbondale National Bank	$12,708.23	
Total Other Assets	10,725.68	
		$23,433.91
Cash in Carbondale National Bank, December 31, 1963		$12,708.23
Outstanding Checks	$ 3,788.78	
Permanent Fund—Cash	350.00	
		$ 4,138.78
Total Uncommitted Cash, Dec. 31, 1963		$ 8,569.45

W. D. Klimstra, Treasurer
Submitted and approved on April 24, 1964

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For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy and one carbon copy should be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. An abstract must accompany each article. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, *Acknowledgments*, and *Literature Cited*.

No footnotes are to be used in the text.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, J. H. 1951. The life cycle of a land snail. Conchol. 26(3): 21-32, 2 tables, 3 figs.
Doe, J. H. 1951. Mineralogy of Lower Tertiary deposits. McGraw-Hill Book Co., New York. iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908, p. 21) or (Doe, 1908, p. 21); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

Photographs should be hard, glossy prints of good contrast. Graphs, maps and other figures reproduce best when prepared for at least one-half reduction; lettering, numerals, etc. on all figures in a manuscript should be worked out to proper size for such reduction. Line widths, letter size, etc., should be uniform from figure to figure within a published paper. Figures should be drawn on good quality white paper or on drawing board. Use only India ink. Use a lettering device (Leroy or Wrico) for numerals and words; do not print "free-hand."

Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at the time galley proofs and manuscripts are returned to the Editor.

EDWIN C. GALBREATH,
Department of Zoology,
Southern Illinois University,
Carbondale, Illinois.

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Transactions

of the

Illinois State Academy of Science

Volume 58
No. 4
1965

Springfield, Illinois

TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

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TRANSACTIONS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME 58 - 1965 No. 4

Illinois State Academy of Science

affiliated with the

Illinois State Museum Division

Springfield, Illinois

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

Otto Kerner, *Governor*

December 15, 1965

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THE BIRD SPRING GROUP, CHESTERIAN THROUGH WOLFCAMPIAN, AT ARROW CANYON, ARROW CANYON RANGE, CLARK COUNTY, NEVADA

V. A. M. LANGENHEIM AND R. L. LANGENHEIM, JR.
401 W. Vermont, Urbana, and University of Illinois, Urbana

ABSTRACT. — Approximately 3500 feet of Chesterian through Wolfcampian rock exposed in Arrow Canyon are assigned to the Bird Spring Group. At this locality the group comprises five units of formational rank: The Battleship Wash Formation—80 feet of cliff-forming limestone of Chesterian age, the BSb unit—240 feet of shale and sandy limestone of probable Springeran age, the BSc unit—2200 feet of limestone and cherty limestone of Springeran (?) through Missourian age, the BSd unit—320 feet of interbedded limestone and shaly limestone of Missourian, Virgilian and Wolfcampian age, and the BSe unit—530 feet of dolomite and limestone of Wolfcampian age.

The following description of the Late Paleozoic cyclic limestone sequence at Arrow Canyon is part of a continuing project to furnish a reference section for Late Cambrian through Permian rocks in the southern part of the Cordilleran miogeosyncline. Detailed description of the entire Bird Spring Group exposed in this locality should provide a useful datum for investigators considering regional Late Paleozoic stratigraphy and establish stratigraphic relationships of previously described invertebrate fossils (McCutcheon and Wilson, 1961, 1963; Wilson, 1963; Wilson, Waines and Coogan, 1963).

Arrow Canyon is superposed across the northern end of the Arrow Canyon Range approximately 50 miles N. E. of Las Vegas, Nevada (Fig. 1). Certain strata well-exposed in the walls of this canyon range in age from Late Mississippian to Permian and have been placed within the Bird Spring Group.

Procedure. — Stratigraphic sections were measured by tape and compass and traverse data were reduced to stratigraphic thickness with the aid of Mandelbaum and Sanford's (1952) tables. Representative samples were collected from each separately described bed and field descriptions are supplemented by study of polished sections and insoluble residues. Selected fusulinids have been identified for stratigraphic control and only a few of the more prominent or stratigraphically significant larger invertebrates have been studied.

STRATIGRAPHY

Previous Work. — Spurr (1903) first reported Carboniferous rocks at the northern end of the Arrow Canyon Range, but referred to the mountains as the Meadow Valley Range. Longwell (1928, 1949, 1952) briefly mentioned these rocks, but noted in particular the excellent exposures in Arrow Canyon. Later, Bowyer, Pampeyan and Longwell (1958) showed the distribution of Pennsylvanian and Permian rocks on a geologic map of Clark County. Stratigraphic studies by Bissell (1962b, c) refer to, but do not describe sections in the Arrow Canyon Range. Brill (1963, Fig. 14) presented a generalized columnar sec-

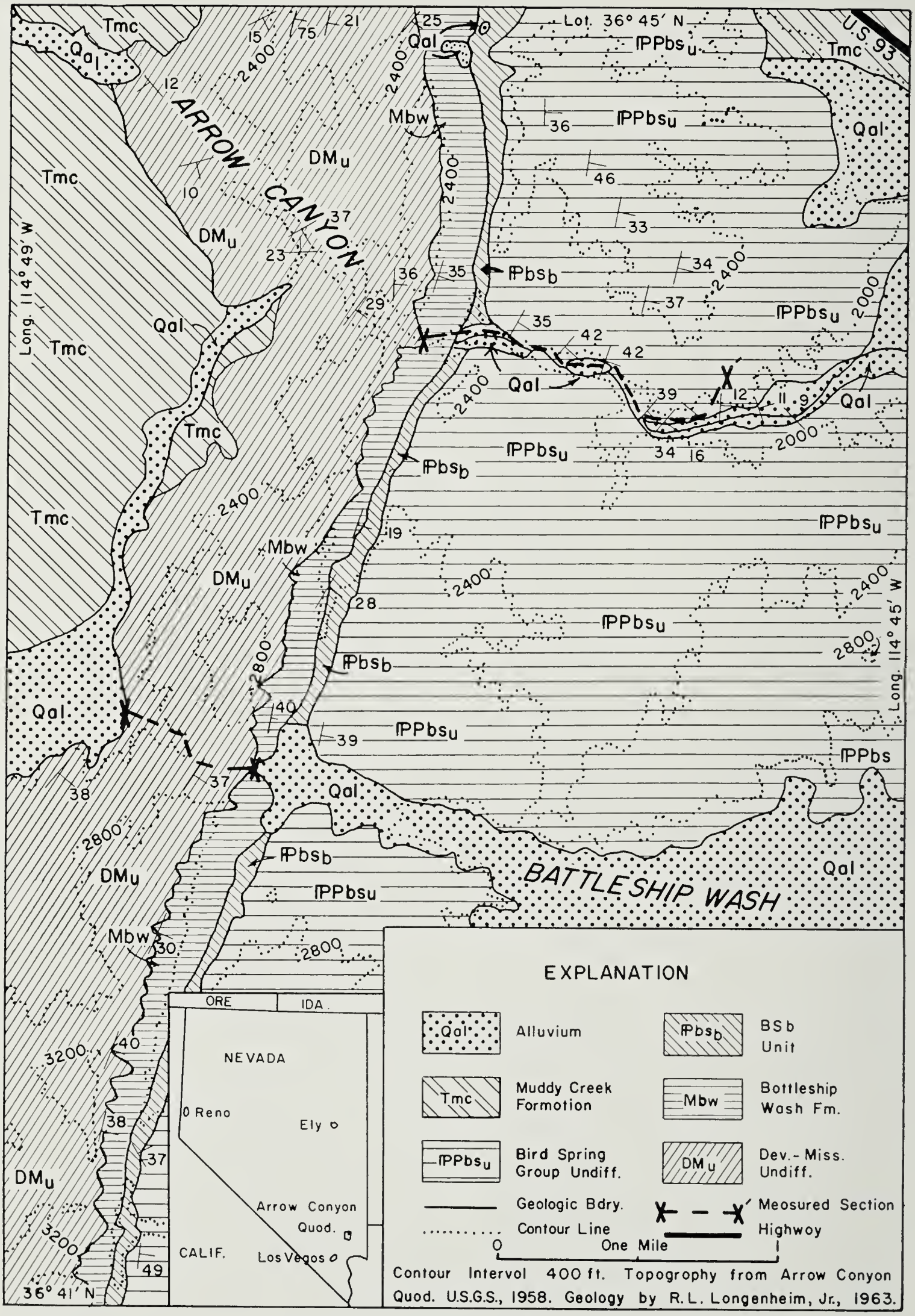

FIGURE 1.—Location map of Arrow Canyon, Arrow Canyon Range, Clark County, Nevada.

tion of the strata in question and a short discussion of their aspect and fauna. Coogan (1964) has provided a more detailed description of the Chesterian through mid-Atokan portion of the sequence. Other pertinent studies have been reported by Langenheim et al. 1962), McCutcheon and Wilson (1961), Wilson, Waines and Coogan (1963), and, in unpublished theses, by Duley (1957), Welsh (1959), Coogan (1962) and V. A. M. Langenheim (1964).

Stratigraphic Nomenclature. — Longwell (1921, 1928 described Pennsylvanian and Permian rocks in the Muddy Mountains, and assigned them to the Callville Limestone, whereas Glock (1929) employed the name, "Bird Spring", for similar rocks in the Spring Mountains. Later, the Bird Spring Formation was described by Hewett (1931) in greater detail. These formation concepts, as erected, distinguish strata between the cliff-forming Mississippian rocks of the region and redbeds identified as the "Supai" Formation (Fig. 2). Although the Callville concept enjoys priority, we prefer to refer the Arrow Canyon rocks to the Bird Spring Formation because its original description is more complete, because there are no doubts concerning the precise limits of its application in the type area, and because it has been employed by most workers in the area.

In addition to these two formational concepts, applicable to the entire sequence, several less inclusive units have been proposed. Longwell (1921, 1928) defined as the Blue Point Limestone a cliff-forming limestone containing a "Brazer fauna". This unit incorporates beds between the overlying Callville Limestone and the Lower Mississippian Rogers Spring Limestone, but was mapped by Longwell as part of an undivided sequence with the Rogers Spring Limestone. Longwell (personal communication, 1955) has since suggested that the Blue Point Limestone may be equivalent to some part of the Indian Springs Member of the Bird Spring Formation. Examination of sections in the Muddy Mountains (Langenheim, 1956), however, failed to locate fossils clearly identical to those reported by Longwell, and Longwell's original collections appear to have been lost or mislaid in the collections of the U. S. Geological Survey. As a consequence, the Bluepoint Limestone could possibly be correlated with either the Indian Springs Member or with the uppermost Monte Cristo Formation of most authors.

Longwell and Dunbar (1936) recognized a Chesterian faunal assemblage in the lowermost, shaly portion of the Bird Spring Formation in the type area. On this basis, they assigned these rocks to what they called the Indian Springs Member of the Bird Spring Formation. The name, "Indian Springs," however, is preoccupied by the Indian Spring Shale and the Indian Spring Redbeds, Silurian of Maryland (Swartz, 1923) and by the Indian Springs Shale, Chesterian of Indiana (Malott and Thompson, 1920). We recommend abandonment, therefore, of the name, "Indian Springs", for the Chesterian, lowermost member of the Bird Spring Formation of southern Nevada.

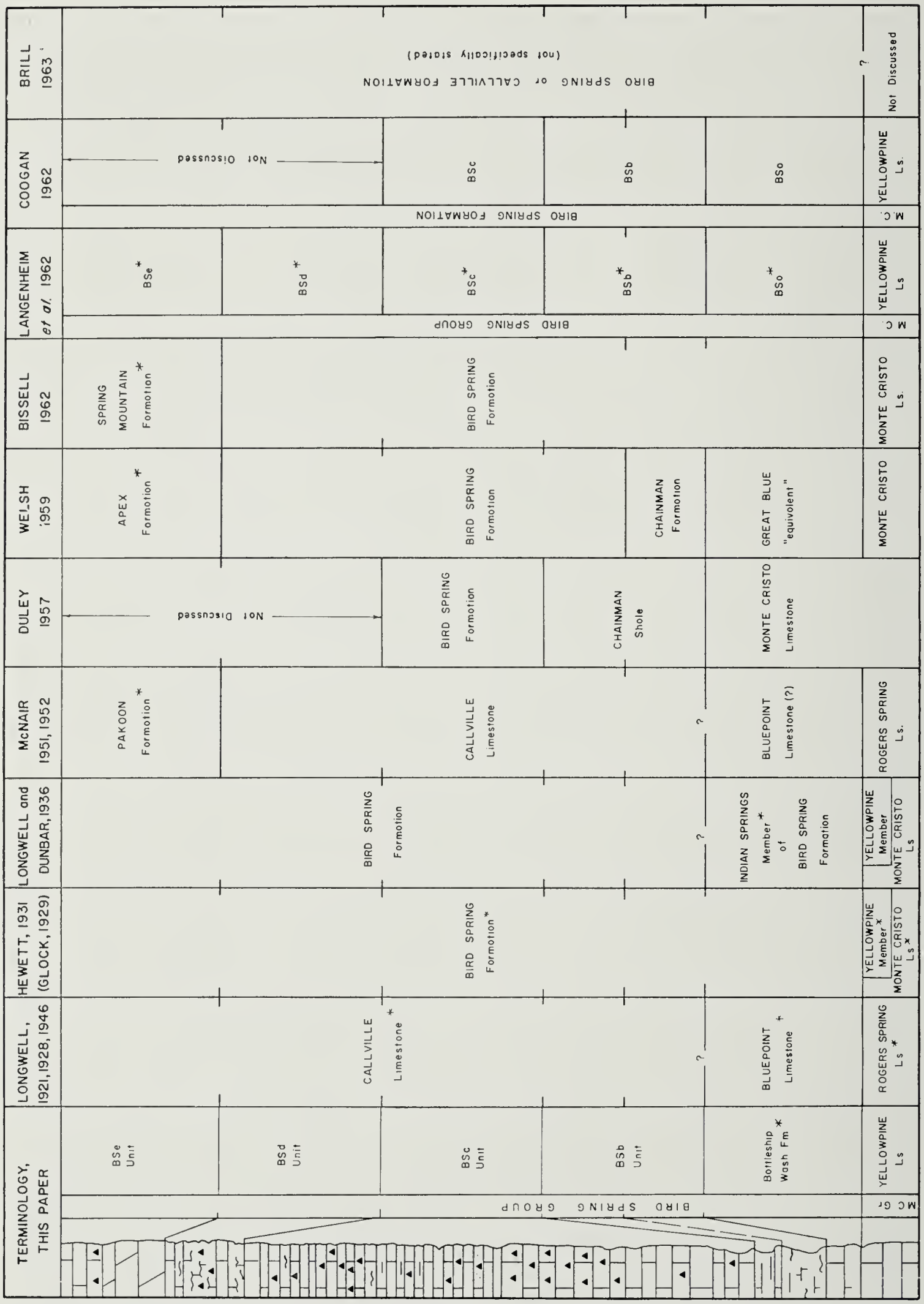

FIGURE 2.—Chart showing stratigraphic nomenclature applied to late Paleozoic rocks of southern Nevada. An asterisk indicates the original description of a unit.

Permian rocks, originally included in the Callville Limestone or Bird Spring Formation, have been assigned by certain investigators to separate formational units. McNair (1951) has defined the Pakoon Formation as consisting of dolomitic, Permian rocks, formerly included in the Callville Formation, cropping out in northwestern Arizona and adjacent areas. The Spring Mountain Formation, defined by Bissell (1962b, c), includes Wolfcampian and Leonardian rocks formerly included in the Bird Spring Formation.

Welsh's (1959) more elaborate classification includes separate Pennsylvanian and Permian formations in both a basinal and platform facies within Clark County. The Callville and Pakoon Formations, in the sense of McNair (1951), are recognized as the platform facies, the Bird Spring Formation is restricted to Pennsylvanian rocks in the basinal facies and a new formation, the Apex Formation, is proposed for Permian rocks in the basinal facies.

We (Langenheim et al., 1962; Langenheim, V. A. M., 1964) have subdivided the Bird Spring Formation into locally useful units, BSa through BSe. The BSa unit is of the proper lithology, age, and stratigraphic position for assignment to the Blue Point Limestone, but the latter was not adequately defined and definite correlation appears to be impossible. The BSa and BSb units together probably constitute the "Indian Springs Member" as described by Longwell and Dunbar (1936). Doubt remains, however, as to whether the tops of the BSb unit and the Indian Springs Member are to be correlated. Perhaps all or part of the BSb unit should be more properly assigned to the White Pine Group in either the Chainman Shale or Hamilton Canyon Formation. The BSc and BSd units together are roughly equivalent to the restricted Bird Spring Formation of Bissell (1962b, c) or Welsh (1959), and the BSe unit approximates the Pakoon Formation of McNair (1951), the Spring Mountain Formation of Bissell (1962b, c) or Apex Formation of Welsh (1961). Differences between the bounding limits appear, however, because the Pennsylvanian-Permian boundary apparently lies within the BSd unit at a horizon not readily recognizable for mapping purposes.

Except for the BSa unit, we have as yet not adequately demonstrated the other informal units to be readily useful in mapping, and, for this reason, we prefer not to propose them as formational units. The BSa unit, however, has a distinctive lithology and serves as a useful map unit throughout its extent in the Arrow Canyon Quadrangle. For these reasons we are formally designating it the Battleship Wash Formation of the Bird Spring Group.

Descriptive Stratigraphy (Figs. 3, 4). — In Arrow Canyon the Bird Spring Group is approximately 3500 feet thick and is almost entirely of limestone with the exception of one prominent dolomite interval about 300 feet thick near the top and approximately 240 feet of predominantly shaly rocks near the base. Portions are abundantly cherty.

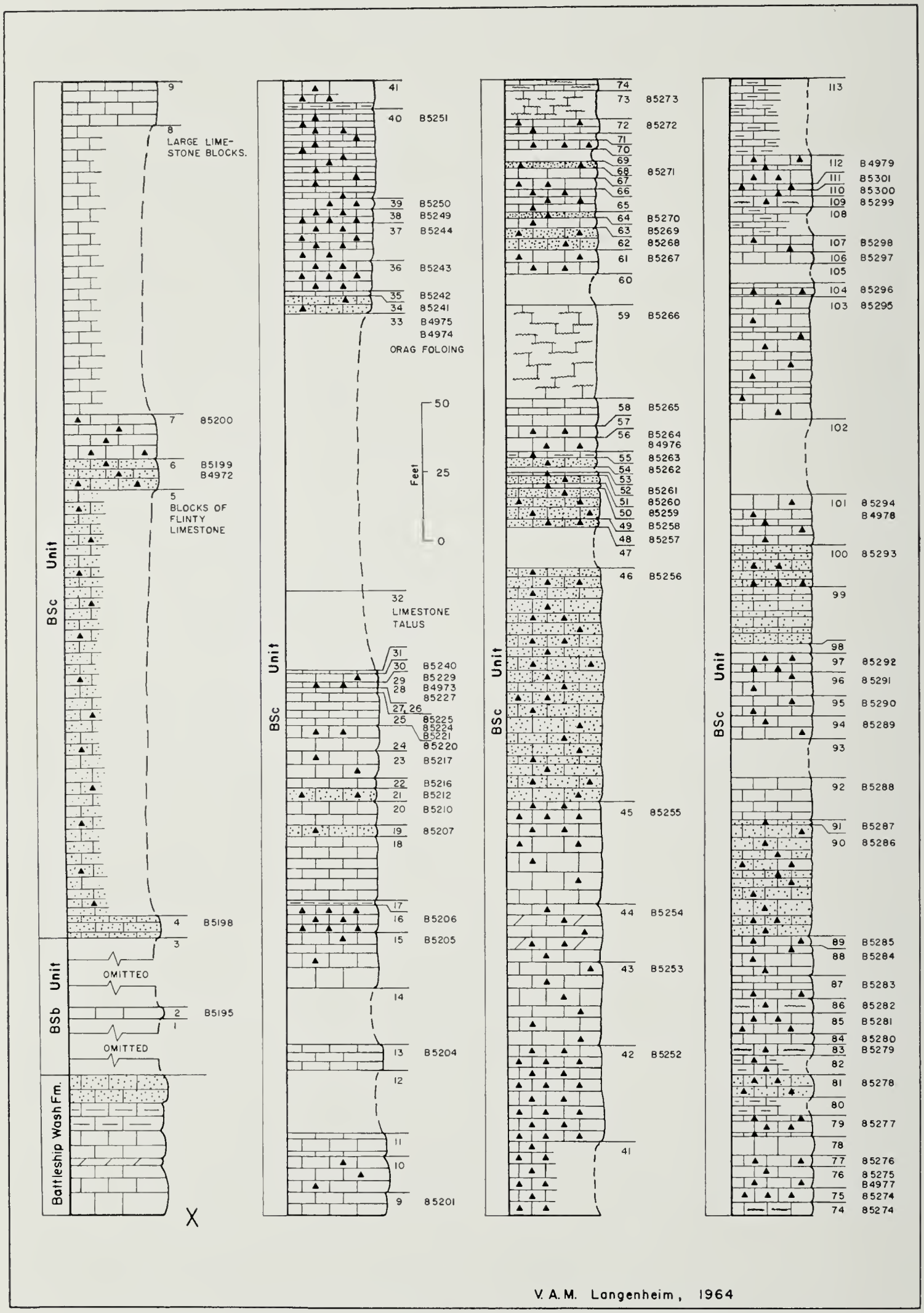

FIGURE 3.—Columnar section of the lower portion of the Bird Spring Group as exposed in Arrow Canyon.

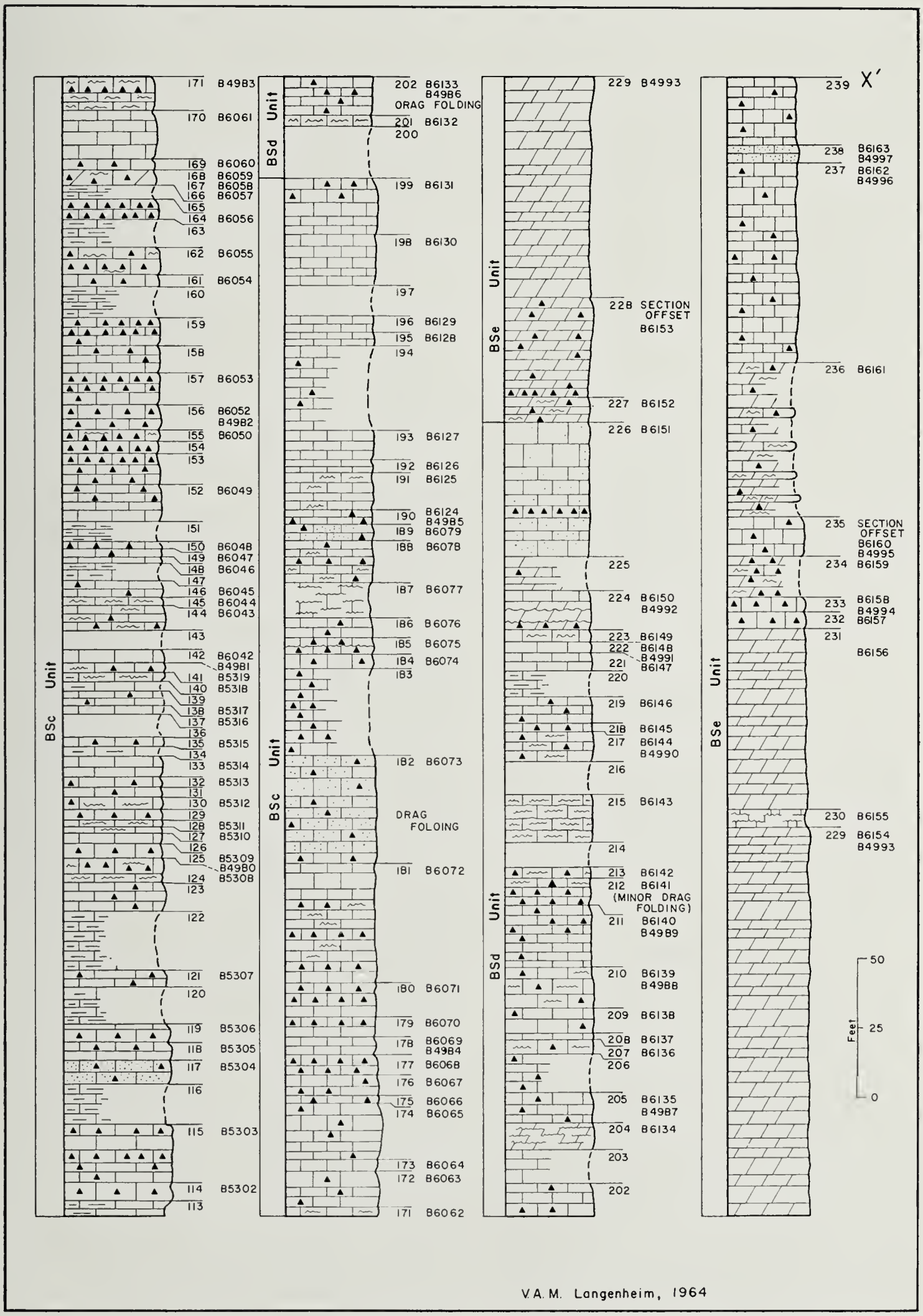

FIGURE 4.—Columnar section of the upper portion of the Bird Spring Group as exposed in Arrow Canyon.

Battleship Wash Formation. — The basal contact with the underlying Monte Cristo Group is well exposed at the type section in the north wall of Arrow Canyon at the lower entrance to the deep and narrow upper gorge. Here an interbedded sequence of cherty, sandy limestone and brown-weathering, calcareous sandstone rests on thick-bedded, fine-to medium-grained, gray limestone in the Monte Cristo Group. The sandstone, though discontinuous and inconspicuous, is a most useful feature in recognizing the contact and is the most important physical evidence of an interruption in deposition. Species of *Faberophyllum*, present in the lowermost sandy unit, also occur in the Brazer Group of northern Utah (Duley, 1957; Parks, 1951) and have been identified as Chesterian, whereas *Lithostrotionella* sp. and other fossils in the uppermost Yellowpine Limestone of the Monte Cristo Group are Meramecian or possibly Osagian. Thus the apparent hiatus at this contact amounts to all or part of Meramecian time and provides further evidence of a disconformity.

The basal sandstone member at the type section is a 4½ foot interval of interbedded sandy limestone and calcareous sandstone in beds approximately 4 inches to 1 foot thick. These rocks are slabby and weather readily to form a bench or reentrant that is easily overlooked in the field because of debris derived from rocks above and below. At Arrow Canyon, the basal member contains abundant specimens of *Faberophyllum* sp.

A middle member, approximately 65 feet thick at the type locality, consists of medium-grained, thick-bedded limestone characterized by blocky jointing and strikingly parallel bedding. These rocks weather dark olive-gray in contrast to the lighter gray rocks of the Monte Cristo Group. In addition, these rocks are spar cemented in contrast to the lime-mud cemented limestone below. Fossils are notably absent.

An uppermost member consists of about 8 feet of medium-grained limestone which weathers purplish-gray and is more thinly bedded than the middle member. Bedding plane surfaces bear an interesting association of *Stigmaria* sp., shark teeth, solitary rugose corals and spiriferid brachiopods.

BSB unit. — This unit consists of 243 feet of shaly rocks and characteristically forms a prominent strike valley or bench. Exposures are poor and all but three feet of the unit are covered on the line of the traverse. Scattered outcrops show that, although black and red shale is prominent in the covered sequence, argillaceous limestone and calcareous sandstone probably are as abundant. Bed 2, a characteristic limestone, is fine-grained, and weathers rusty. It has approximately 5% insoluble residue, chiefly fine sand and silt and contains the same brachiopod fauna as that occurring in the basal part of the BSc unit.

BSc unit. — Strata aggregating about 2200 feet in the Arrow Canyon section constitute this heterogeneous unit dominated by different kinds of limestone some of which are cherty. These rocks, together with shale and sandstone, occur in what is regarded to be a cyclical alternation.

Beds 5 through 8, 285 feet thick, are composed chiefly of fine-grained, gray limestone which weathers gray to rusty. Silicified fossils are locally abundant and the following brachiopods are especially prominent: *Schizophoria texana*, *Punctospirifer campestris*, *Spirifer occiduus*, and *Antiquatonia hermosana*. An insoluble residue as much as 27% is composed chiefly of fine sand and silt.

Beds 9 through 31, comprising about 210 feet, are relatively thick-bedded limestone. Limestones in this sequence range from fine- to coarse-grained; they are predominantly dark gray and weather light gray. Chert is sparse in the lower half of this unit but becomes relatively abundant stratigraphically upward. Fossils are more conspicuous in the upper half and include chiefly brachiopods, bryozoans and echinoderm fragments.

Beds 32 and 33, approximately 150 feet thick, are covered on the line of traverse and are drag folded. They are composed of more argillaceous limestone. Locally abundant brachiopods within this sequence include *Spirifer occiduus*, *Hustedia rotunda*, *Cleiothyridina orbicularis*, *Punctospirifer campestris*, *Linoproductus prattenianus*, *Antiquatonia hermosana*, and *Orthotetes* cf. *O. occidentalis*.

Beds 34 through 45, approximately 230 feet thick, are composed of cherty limestone ranging from fine- to coarse-grained and are chiefly dark gray to medium gray. The insoluble residue generally is less than 10%. Brachiopods, bryozoans and echinoderm fragments are abundant and rugose corals occur in beds 42 and 43.

Beds 46 to 54, approximately 125 feet thick, are characterized by insoluble residues ranging from 10% to 32%. These dark gray, fine-grained limestone beds weather gray to buff. Fossils are not prominent.

Beds 55 through 60, approximately 65 feet thick, consist of limestone grading upward into calcareous siltstone. The fine- to medium-grained, gray limestone is cherty and contains about 10% insoluble residue. Silicified brachiopods occur in bed 56. The gray calcareous siltstone weathers to gray and buff and contains chert nodules. It is composed of approximately 60% insoluble fine sand and silt.

Beds 61 through 89, about 175 feet thick, are composed of repeated sequences of relatively thin beds of chert and limestone, silty limestone, and calcareous siltstone. Insoluble content ranges to 53% but, within the limestone, is from 3 to 15%. Quartz fine sand and silt dominates the residues. These light to dark gray rocks weather gray or buff. Brachiopods, bryozoans, and echinoderm fragments are present.

Beds 90 to 91, approximately 43 feet thick, consist of medium- to coarse-grained limestone with insoluble residues of quartz fine sand and silt ranging from 20% to 45%.

Beds 92 through 98 are composed of about 65 feet of relatively chert-free, fine- to coarse-grained limestone. Insoluble residues are either less than 10% of sand and silt or are larger and composed of clay.

Beds 99 and 100 total 35 feet thick and are composed of coarse-grained, sandy limestone which is light gray and weathers buff to brown.

Beds 101 through 151, approximately 190 feet thick, are characteristically shaly and relatively chert-free. This easily eroded sequence is composed of thin units of fine- to medium-grained, gray to black, sandy or silty limestone alternating with poorly exposed, relatively thick units of thin-bedded shaly, nodular limestone. Insoluble residues, chiefly of fine sand and silt, range from 5% to 25%. *Chaetetes favosus* occurs in bed 112. Brachiopods, fenestellid bryozoans, solitary corals and fusulinids are locally abundant.

Beds 152 through 169, approximately 125 feet thick, are characterized by more abundant chert. Insoluble residues are generally less than 10% but range from 1.2% to 52%. Limestones range from fine- to medium-grained. Shaly limestone is confined to beds 160, 163 and 165 and bed 166 is dolomitic. Brachiopods and fenestellid bryozoans are the most prominent fossils, but *Caninia* sp. occurs in bed 156.

Beds 170 through 182 consist of about 190 feet of relatively thick-bedded, fine- to coarse-grained limestone. Chert is moderately abundant, but shaly or silty layers are absent. Insoluble residues range from a trace to from 20% to 30%. These cliff-forming rocks cause a narrows in the canyon. Bed 182 is notably drag-folded. Brachiopods and bryozoans are locally abundant and *Wedekindellina* (?) sp. occurs in beds 174 and 176.

Beds 183 through 199, about 200 feet of rock, are chiefly of thick-bedded, fine-grained limestone, but include several prominent interbedded layers of calcareous siltstone and silty limestone. Chert is largely confined to the lower half of this sequence. Insoluble residues of silt and fine sand range from a trace to about 25% in the limestone and 30% to 50% of the silty rock is carbonate. *Fusulina* (?) sp. occurs in bed 190 and brachiopods and bryozoans occur locally throughout the sequence.

BSd unit. — This unit includes beds 200 through 226 and is about 320 feet thick at Arrow Canyon. It is characterized by resistant thick-bedded, relatively pure limestone sequences alternating with nodular, shaly, cherty intervals which erode to form gullies and benches.

The limestone sequences range from 10 to 50 feet thick and generally are composed of layers ranging from a few inches to 2 feet thick. A few, exceptional layers in bed 226 are as much as 8 feet thick. The limestone is chiefly fine-grained, but medium-grained limestone, with or without scattered coarse crystals, is present. Insoluble residues of fine sand or silt are characteristic and range from 5% to 20%. Beds 224 and 225 are dolomite. The silty sequences are as much as 20 feet thick, and, although largely covered, are characterized by layers from 6 inches to 1 foot thick of nodular aspect.

Fusulinids are abundant in the limestone beds. *Triticites* spp., including *T. californicus*, occur in beds 210, 212, and 223. *Schwagerina* sp. has also been noted in bed 223. Bryozoans, brachiopods, rugose corals, and *Syringopora* spp. are locally abundant.

BSe unit. — Approximately 530 feet of this unit were measured and described. The lower three-fifths is dolomite and

forms the prominent cliffs capping outcrops of the BSd unit. These rocks are exposed where steeply dipping beds flatten abruptly to the east in Arrow Canyon. Beds 227 to 228 are composed of about 45 feet of fine-grained, gray dolomite which weathers buff. Layers are as much as 3 feet thick and contain scattered chert nodules. Insoluble residues of white silt range from 5% to 20%. Beds 229 to 231 comprise about 290 feet of similar, but chert-free, dolomite.

The upper two-fifths of the measured part of the unit, about 195 feet of rock in beds 232 through 239, consists of fine-grained, light gray limestone in layers as much as 3 feet thick. Minor dolomite layers are interbedded and scattered chert nodules are present. Scattered fossil occurrences include *Kleopatrina ftatateeta* and *Syringopora mccutcheonae* in bed 237; *Durhamina cordillerensis* in bed 233; and fusulinids in beds 232, 235, 236, and 238.

Age and Correlation.—Although relatively few fossils have been described and illustrated from Pennsylvanian and Permian rocks in the Great Basin, Bissell (1962a, b) and Brill (1963) have published zonal schemes for these rocks based on fusulinid occurrences. Coogan (1962, 1964) has outlined a somewhat more detailed subdivision of pre-Desmoinesian rocks in which he utilizes the ranges of fusulinids and other invertebrates and Wilson and Langenheim (1962) have recognized a set of coral zonules in the Wolfcampian and Leonardian. These schemes, along with the unpublished fusulinid zone classification of Welsh (1959), are arranged according to the standard stages and zones for Pennsylvanian and Permian rocks (Moore and Thompson, 1949; Thompson, 1948) in Figure 5.

Thirty-one fossil invertebrate species, determined in the course of this study, are tabulated in Figure 6 according to their stratigraphic occurence. Some of these species can be related to one or another of the already described zones and, therefore, serve to correlate the Arrow Canyon rocks with rocks elsewhere in the Great Basin or with the standard North American Pennsylvanian and Permian biostratigraphic units. Ranges of other species are not well known, and it is hoped that determination of their range at Arrow Canyon may be useful for future stratigraphic work in the region.

Punctospirifer campestris, *Schizophoria texana*, *Cleiothyridina orbicularis* and *Antiquatonia hermosana*, occurring in beds 6, 29, and 33, along with other brachiopods and *Acanthopecten* sp., are all characteristic of the *Rhipidomella nevadensis* fauna of the Great Basin. N. G. Lane (1963) has described *Schizophoria texana*, *Orthotetes occidentalis*, and *Anthracospirifer birdspringensis* (*Spirifer occiduus* of this report) and assigns them to the late Morrowan. B. O. Lane (1962), however, reports *Spirifer occiduus*, *Punctospirifer campestris* and *Antiquatonia hermosana* occurring stratigraphically above *Fusulinella* and *Profusulinella* in the White Pine Range, thereby extending their ranges at least to the middle Atokan.

Coogan (1962, 1964) assigns the entire BSb unit and the basal 95 feet of the BSc unit at Arrow Canyon, which includes our bed 6, to his *Flexaria-Reticularina-Michelinia* Faunizone. The overlying *Millerella marblensis-Staffella expansa-Caninostrotion* sp. Faunizone (Coogan, 1962, 1964) apparently includes our beds 29 and 33 in the lower portion. According to Coogan (1962, 1964) *Antiquatonia hermosana*, *Schizophoria texana* and *Spirifer occiduus* range throughout the *Millerella marblensis* etc. Faunizone and *Reticularina campestris* (*Punctospirifer campestris* of this report) may occur in the lower portion.

Coogan (1962, 1964) places the *Flexaria* etc. Faunizone somewhere between the Late Chesterian and the Early Morrowan but declines to recognize Springeran rocks in the Great Basin. He places the *Millerella expansa* etc Faunizone in the Morrowan.

Welsh (1959), on the basis of his recognition of *Rhipidomella nevadensis*

ST'D. STAGES and ZONES		BISSELL, 1962 a b		BRILL, 1963	WELSH, 1959		Ⓐ WILSON and LANGENHEIM, 1962 Ⓑ COOGAN, 1962
GUADALUPIAN	*POLYDIEXODINA*	GUADALUPIAN					Ⓐ
	PARAFUSULINA		*Leella fragilis*				?
LEONARDIAN		LEONARDIAN	*Parafusulina (Parafusulina) bosei*				*Heritschiodes hillae* *Orionastrea hudsani*
			Parafusulina (Skinnerella) diabloensis				?
			Parafusulina (Skinnerella) schucherti	*Schwagerina hessensis, S. hawkinsi, S. guembeli, S. crassitectoria,* and *Pseudofusulina lativentra*			? *Durhamina cordillerensis*
WOLFCAMPIAN	*PSEUDOSCHWAGERINA*	WOLFCAMPIAN	*Schwagerina youngquisti*	*Schwagerina wellesensis, Pseudoschwagerina gerantica, S. compacta,* and *Monodiexodina linearis*	*Pseudoschwagerina* cf. *P. convexo, P.* cf. *P. gerontica, S.* cf. *S. linearis, S.* cf. *S. diversiformis*		(Zone 2 of Easton, 1960)
			Schwagerina elkoensis	*Triticites californicus, T. cellamagnus, Schwagerina emaciata,* and *S. complexa*	*Schwagerina* cf. *S. neolata, S.* cf. *S. eolata, Pseudofusulina* cf. *P. moranensis*		? *Syringopora mccutcheonae -Thysanophyllum princeps* (Zone 1 of Easton, 1960)
			Triticites cellamagnus				? *Caninia hanseni*
VIRGILIAN	*TRITICITES*	VIRGILIAN	*Triticites cullomensis*	*Triticites cullomensis, T. hobblensis, T. plummeri*	Ventricose *Triticites*	*Dunbarinella*	
			Triticites kellyensis			*Waeringella*	
			Triticites plummeri				
MISSOURIAN		MISSOURIAN	*Kansanella (Kansanella) grangerensis*	Primitive *Triticites spp.* such as *T. springvillensis* and *T. provoensis*	Cylindrical *Triticites*		
			Triticites provaensis				
			Triticites springvillensis			*Waeringella ultima*	
DESMOINESIAN	*FUSULINA*	DESMOINESIAN	*Fusulina megista*	*Fusulina spp.*	*Fusulina*		Ⓑ
			Wedekindellina euthysepta	*Wedekindellina spp.*		Subzone of *Wedekindellina*	
ATOKAN	*FUSULINELLA*	DERRYAN	*Fusulinella acuminata*	*Profusulinella spp.* and primitive spp. of *Fusulinella, Chaetetes sp.*	*Fusulinella*		*F. devexa* *F. acuminata - Komia sp.* (*Multitheco-pora sp.-Chaetetes sp.*) *F. fugax - Chaetetes sp.*
	PROFUSULINELLA		*Profusulinella apodacensis*		*Profusulinella*		*P. decora - Chaetetes* *P. copiosa - Caninia torquia*
MORROWAN	*MILLERELLA*	MORROWAN	*Millerella marblensis*	*Millerella spp., Eoschubertella spp., Hustedia miseri*	*Millerella* and *Paramillerella*		*Millerella marblensis -* *Staffella expansa -* *Caninostrotion sp. A.*
SPRINGERAN		SPRINGERAN	*Paramillerella circuli*	*Rhipidomella nevadensis, Schizophoria texana, Chonetes sp.*	*Rhipidomella nevadensis*		Morrowan, Chesterian or neither: *Flexaria*
Chest.		Late Chest.	*Atetsuella meandra*				*Cravenoceras merriami - Mooreoceras sp.*

FIGURE 5.—Pennsylvanian and Permian biostratigraphic units employed in the Great Basin Province.

UNIT	BSc Unit													BSd Unit						BSe Unit			
FOSSILS \ BED	6	29	33	42	56	101	112	125	142	171	174	176	190	205	210	211	212	217	223	229	233	237	238
FORAMINIFERA																							
Fusulina (?) sp.													X										
Schwagerina sp.																			X				
Triticites sp.															X								
Triticites californicus																			X				
T. cf. T. californicus																	X						
Wedekindellina sp.											X	X											
COELENTERATA																							
Canina sp.						X																	
Chaetetes favosus							X																
Durhamina cordillerensis																					X		
Kleopatrina ftatoteeta																						X	
Pseudozaphrentoides ordinatus																		X					
Stereostylus nebulus								X															
Syringopora cf. S. catenoides														X									
S. mccutcheonae																						X	
S. (?) mozarti														X									
S. multattenuata														X				X					
S. cf. S. multattenuata																X				X			X
BRACHIOPODA																							
Antiquatonia hermosana	X	X	X																				
Cleiothyridina orbicularis			X																				
Composita subtilita								X															
Hustedia rotunda			X																				
Linoproductus prattenianus			X	X	X			X															
Meekella sp.	X																						
Neospirifer cameratus								X															
Orthotetes cf. O. occidentalis			X																				
Punctospirifer campestris	X		X																				
P. kentuckyensis										X													
Schizophoria texana	X																						
Spirifer occiduus	X		X		X			X						X									
Wellerella tetrahedra									X														
MOLLUSCA																							
Ancanthopecten sp.			X																				
SAMPLE NUMBERS	B4972; 5199	B4973; 5229	B4974	B5252	B4976; 5264	B4978; 5294	B4979	B4980; 5309	B4981; 6042	B4983; 6062	B6065	B6067	B4985; 6124	B4987; 6135	B4988; 6139	B4989; 6140	B6141	B4990; 6144	B6149	B4993; 6154	B4994; 6158	B4996; 6162	B4997; 6163

FIGURE 6.—Checklist of fossils from the Bird Spring Group at Arrow Canyon.

in the Arrow Canyon section assigns rocks apparently equivalent to our beds 5 through the basal ¼ of bed 8 to the *Rhipidomella nevadensis* zone. His correlation of these rocks is somewhat ambiguous, however, inasmuch as he assigns the collections to the Morrowan in his description and illustration of the columnar section (Welsh, 1959, p. A-105, Enclosure 12) but limits occurrences of *Rhipidomella nevadensis* to the zone of that name (Welsh, 1959, Table I, p. 26) which he tentatively refers to either the Springeran or Morrowan (Welsh, 1959, p. 25, 30). Our collections from bed 6 fall within this sequence but do not include *Rhipidomella nevadensis;* they do include abundant *Schizophoria texana*, however, a brachiopod which grossly resembles *R. nevadensis.*

Welsh (1959, p. 30) assigns all rocks between the highest occurrence of *R. nevadensis* and the lowest occurrance of *Profusulinella*, his station NAC-177 through NAC-187+(20-30), to the Zone of *Millerella* and *Paramillerella*. This sequence apparently includes our collections from beds 29, 33, 42 and 56.

Coogan (1962, 1964) defined the *Millerella marblensis-Staffella expansa-Caninostrotion* sp. Faunizone at Arrow Canyon and used his units 54 through 124, essentially equivalent to our beds 10 through 107, as the type section. Thus our collections from beds 29, 33, 42, 56 and 101 belong to this Faunizone as defined by Coogan. Coogan (1962) reports the following species from this zone which have also been collected here by us: *Antiquatonia hermosana, Hustedia* cf. *H. miseri* (*H. rotunda* of this report), *Linoproductus prattenianus, Spirifer occiduus*, and *Reticularina campestris* (*Punctospirifer campestris* of this report).

Welsh (1959) assigns rocks which apparently fall between our beds 101 and 112 to the Zone of *Profusulinella* and Coogan (1962, 1964) apparently recognizes the same zone in our beds 108 through 111. Thus we have no fossils representative of this zone in our collections.

Both Welsh (1959) and Coogan (1962, 1964) apparently assign rocks equivalent to our beds 112 through 144 to the Zone of *Fusulinella.* Our collection of *Chaetetes favosus* from bed 112 is apparently equivalent to Welsh's *Chaetetes* sp. biostrome at his station NAC-789+(10-20) and to the occurrence of *C. favosus* reported by Coogan (1962, 1964) in his unit 162. Coogan's unit 160 apparently also is included within our bed 112 and is assigned by Coogan to the *Chaetetes favosus-Multithecopora* n. sp. Faunizone and probably to the *Fusulinella fugax-Chaetetes favosus* Faunizone. We, however, have not collected any of the characteristic invertebrates, other than *C. favosus*, reported by Coogan from these rocks.

Our collections from beds 125 and 142 are within the Zone of *Fusulinella* as reported by both Coogan (1962) and Welsh (1959) and both collections appear to fall within the *Fusulinella acuminata-Komia* Faunizone of Coogan. None of the brachiopods or the coral collected by us, however, are reported by Coogan (1962). Welsh's (1959) report of *Composita* sp., *Lophophyllidium* sp., *Neospirifer* sp., *Punctospirifer* sp. and *Spirifer opimus* probably is equivalent to our *Composita subtilita, Sterostylus* n. sp., *Neospirifer cameratus, Punctospirifer kentuckyensis* and *Spirifer opimus.*

Welsh (1959) reports *Wedekindellina* sp. from many beds in an interval apparently equivalent to our beds 135 through 188, and, on this basis, assigns these rocks to the Subzone of *Wedekindellina.* Our two collections of *Wedekindellina* sp, from beds 174 and 176, as well as a collection of *Punctospirifer kentuckyensis* from bed 171 also are from this interval.

Welsh (1959) assigns rocks roughly equivalent to our beds 188 through 195 to the Zone of *Fusulina*, and these rocks, at bed 190, yielded our collection of *Fusulina* (?) sp.

Welsh (1959), on the basis of single occurrences of *Waeringella (Wedekindellina) ultima* and *Triticites* (?) sp., places rocks roughly equivalent to our beds 199 through 210 in the Missourian. Our collection of *Triticites* sp. from bed 210 supports Welsh's conclusion, but our only other Missourian collection, four species of *Syringopora* from bed 205, has little stratigraphic significance.

Welsh's (1959) Zone of ventricose *Triticites* includes rocks ranging from his station NAC-796+20 through NAC-800 and is subdivided into a lower *Waeringella* subzone and an upper *Dunbarinella* subzone. This sequence appears to includes beds 211 through 226, but our collections of Permian fusulinids, *Triticites* cf. *T. californicus* from bed 212 and *T. californicus* and *Schwagerina* sp. from bed 223, contradict Welsh's correlation of these rocks with the Virgilian. Brill (1963), p. 321, fig. 14) also

shows *Triticites californicus* at the base of the Permian and about 50 feet below the base of a prominent dolomite sequence. Therefore the occurrence is probably from our bed 223, which is approximately 75 feet below the base of the thick dolomitic sequence and which has yielded *Schwagerina* sp. and *T. californicus*. Welsh's collection of *Triticites* sp. from a bed ten feet below the base of the dolomite is probably unrelated to our collections or those of Brill (1963).

We have also collected *Syringopora* cf. *S. multattenuata* (beds 211 [illegible]7) and *Pseudozaphrentoides ordi[illegible]* 217) from Virgilian rocks at [illegible]yon. Ross and Ross (1962) described *P. ordinatus* from rocks near the top of the Gaptank [illegible]mation in the Glass Mountains, Texas. Welsh's (1959) reports of *Pseudozaphrentoides* (?) from his Missourian collections NAC-795 and NAC-796 and his Virgilian collection NAC-798+(40-50) may or may not be taxonomically equivalent to our *P. ordinatus*.

Welsh (1959) describes 810 feet of Wolfcampian Apex Formation, placing the base at the bottom of a prominent, thick-bedded, cliff-forming dolomite sequence. We have measured and described only 530 feet o. Wolfcampian rock which includes Welsh's Apex Formation through his station NAC-187 + 90. Welsh (1959) reports many occurrences of *Schwageriana* sp. and *Pseudoschwagerina* sp. within this sequence and we have also collected many fusulinids from these rocks. We, however, have found them difficult to identify because of silicification.

Association of *Kleopatrina ftatateeta* and *Syringopora mccutcheonae* in bed 237 (McCutcheon and Wilson, 1961; Wilson and Langenheim, 1962) is similar to an occurrence in Wolfcampian rocks of the Ely Quadrangle, 200 miles north of Arrow Canyon. In the Ely Quadrangle, however, these corals occur stratigraphically below *Durhamina cordillerensis*, which at Arrow Canyon, occurs in bed 233, below *K. ftatateeta*. This relationship is the reverse of that reported by Wilson and Langenheim (1962, p. 502) and used by them in establishing a sequence of coral zonules in the Ely Quadrangle. Except for the fact that minor morphologic differences between *D. cordillerensis* from Arrow Canyon and from the Ely Quadrangle may prove taxonomically significant, this invalidates the zonules of Wilson and Langenheim (1962) for use throughout the Great Basin. It is possible, however, that the absence of *D. cordillerensis* below *K. ftatateeta* at Ely is consequent upon the fact that there are no Permian rocks of suitable facies below the *K. ftatateeta* occurrance.

Syringopora multattenuata is present in beds 227 and 233, thus significantly extending both the stratigraphic and geographic range of this species (McCutcheon, 1961).

Summary

Approximately 3500 feet of Ch[illegible]terian through Wolfcampian rocks assigned to the Bird Spring Group are well e[illegible]ed in Arrow Canyon in the n[illegible]stern corner of the Arrow C[illegible]yon Quadrangle. These rocks are among the southeasternmost exposures of miogeosynclinal Late Missis[illegible]ppian through Permian rocks in this area, and the exceptional exposure at this locality is well fitted to serve as a regional standard of [illegible]rence for future study.

[illegible]epetitive depositional patterns [illegible] subtle, complex facies relationships have frustrated attempts at region-wide classification of formational units and already described "rock" units ar[illegible] in large part, defined by incom[illegible]letely known biostratigraphic data. For this reason, we formerly emp[illegible]oyed a local classification of info[illegible]al units in which the Bird Spring Formation was treated as a group divided into five units of formational rank: BSa, BSb, BSc, BSd, and BSe (Langenheim et al., 1962). We are now satisfied that the BSa unit has regional significance as a lithologically defined unit and, for this reason, have recognized it as the Battleship Wash Formation.

The Battleship Wash Formation is approximately 80 feet thick at Arrow Canyon. It is characterized by thick-bedded limestone and rests disconformably on the Yellowpine Limestone of the Monte Cristo Group. It is Chesterian.

The BSb unit is approximately 240 feet thick at Arrow Canyon and is characterized by readily eroded shale and sandy limestone. It is probably Springeran.

The BSc unit is approximately 2200 feet thick. It is composed of strikingly layered limestone and cherty limestone which is characteristic of the Bird Spring Group throughout its extent. It ranges in age from Springeran (?) through Missourian.

The BSd unit is approximately 320 feet thick and is composed of alternating sequences of resistant, cliff-forming limestone and readily eroded shaly limestone. It includes late Missourian, Virgilian and early Wolfcampian rocks, thus spanning the Pennsylvanian-Permian boundary. There is no convincing physical or biostratigraphic evidence of an unconformity.

The BSe unit is approximately 530 feet thick in our incomplete measured section. The lower part consists of thick-bedded dolomite and all of the measured and described portion of the unit is Wolfcampian.

Acknowledgments

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PETROLOGY OF THE HORN AREA, BIGHORN MOUNTAINS, WYOMING

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ABSTRACT. — Laramide block-like uplift of the Precambrian basement produced a faulted mountain mass, approximately 27 square miles in area, extending southward from the central Bighorn unit. The core of this uplift contains complexly folded, foliated high-grade metamorphic rocks.

Precambrian rock types include pegmatite, amphibolite, marble, calc-silicate rock, feldspathic rock, biotite schist, and amphibole rocks in addition to the predominant gneiss. Schistosity, mineralogical and lithological layering are conformable throughout the complex with cross-cutting pegmatites being the only exception. These rocks are believed to have originated from regional metamorphism and later alkali metasomatism of supracrustal rocks. Alkali metasomatism, apparently a post-tectonic event and perhaps a late stage of the regional metamorphism, culminated in pegmatitization. Mineral assemblages indicate the staurolite-quartz subfacies, and almandine-amphibolite facies of regional metamorphism.

The Bighorn Mountains (Fig. 1) are a broad, asymmetric, anticlinal uplift between the Powder River Basin on the east and the Bighorn Basin on the west. The north end of the range rises in southern Montana, southeast of the Pryor Range from which it is structurally distinct (Blackstone, 1940). This northern unit is asymmetrical with the steeper flank to the west, and locally is overthrust to the west as in the Five Springs Creek area (Wilson, 1934). Two subsidiary anticlines with the same asymmetry and trend as the northern unit modify the gently dipping east flank. An ill-defined fault zone (Tongue River fault zone) serves as a boundary between the northern and central sectors.

In the central unit, where uplift was greatest, the sedimentary rocks have been extensively removed and much more Precambrian basement is exposed than in the combined northern and southern units. Moreover, the structural asymmetry of the central unit is opposed to that of the northern and southern units. Steep dips with local overthrusts bounded by tear faults mark the east flank whereas the west side is characterized by a gentle monoclinal dip. Asymmetry of subsidiary folded structures at the northern and southern ends of the central unit's east flank conforms to that of adjacent units. For example, Walker Mountain anticline at the north end of the central unit and West Billy Creek, Beaver Creek and Horn anticlinal structures at the south end have their steeper flanks to the west, whereas the central unit proper has its steep flank to the east.

The southern unit is separated from the central unit by the Tensleep fault. This southern unit trends north to north-northeast and is asymmetrical, with the steep flank toward the west; there are several subsidiary anticlines with similar asymmetry which trend north-northwest. A north-northeast trending high angle fault is related to

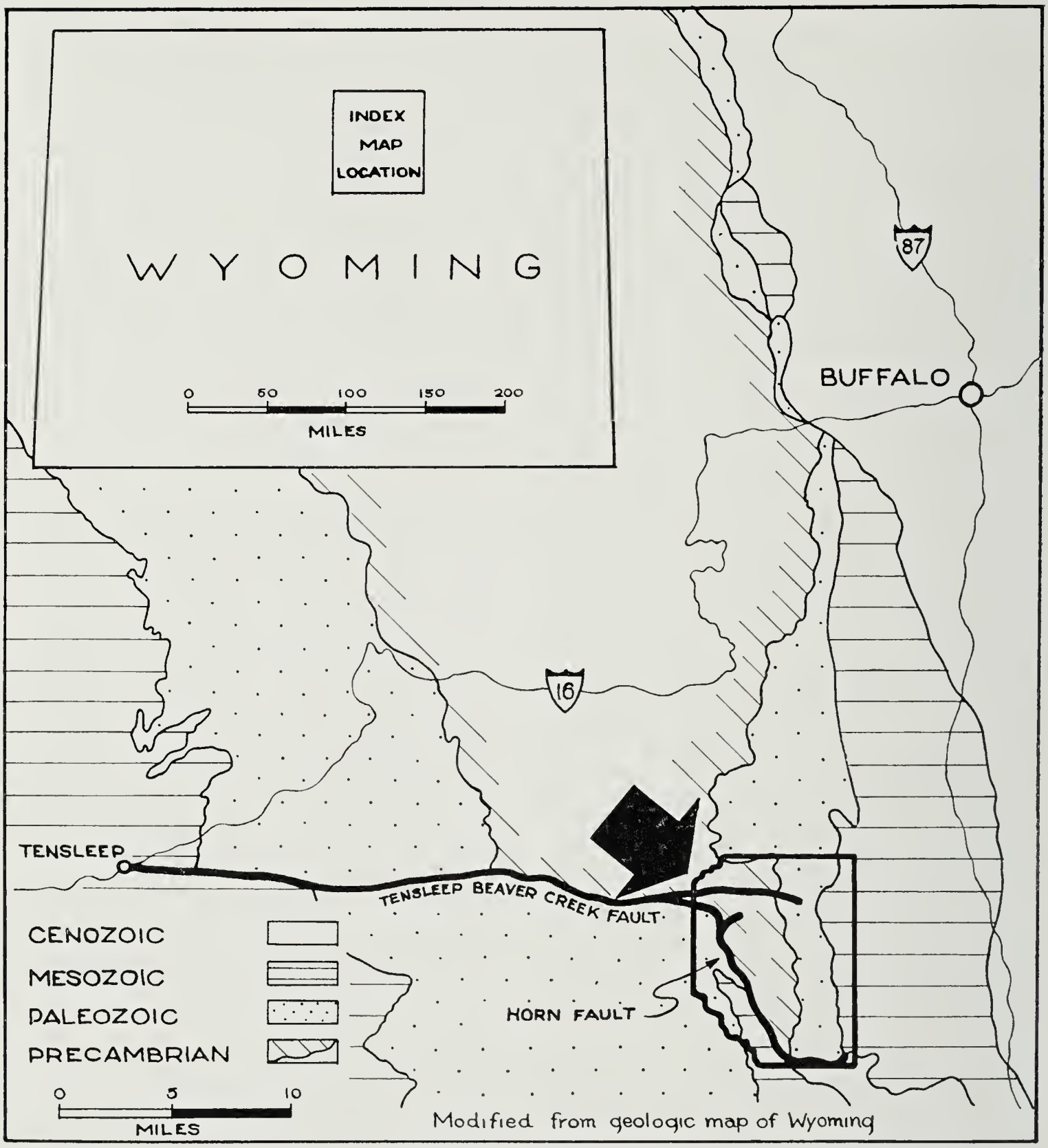

FIGURE 1.—Index map of the central Bighorn unit showing location of the Horn area (large arrow).

uplift of the southern unit. This fault divides into subsidiary ones at the southern terminus of the range where the Bighorns join the westward trending Bridger-Owl Creek Uplift.

The Horn area (Fig. 2) which is of primary concern herein, lies along a portion of the east flank and includes parts of both the central and southern units. A feature identified as the Horn is a relatively small mountain mass which extends as a horn-shaped prominence southward from the central unit. The Horn itself is a block-like uplift of the Precambrian basement with its western and southern boundaries sharply delineated by the Horn fault. This is a high angle, reverse fault along

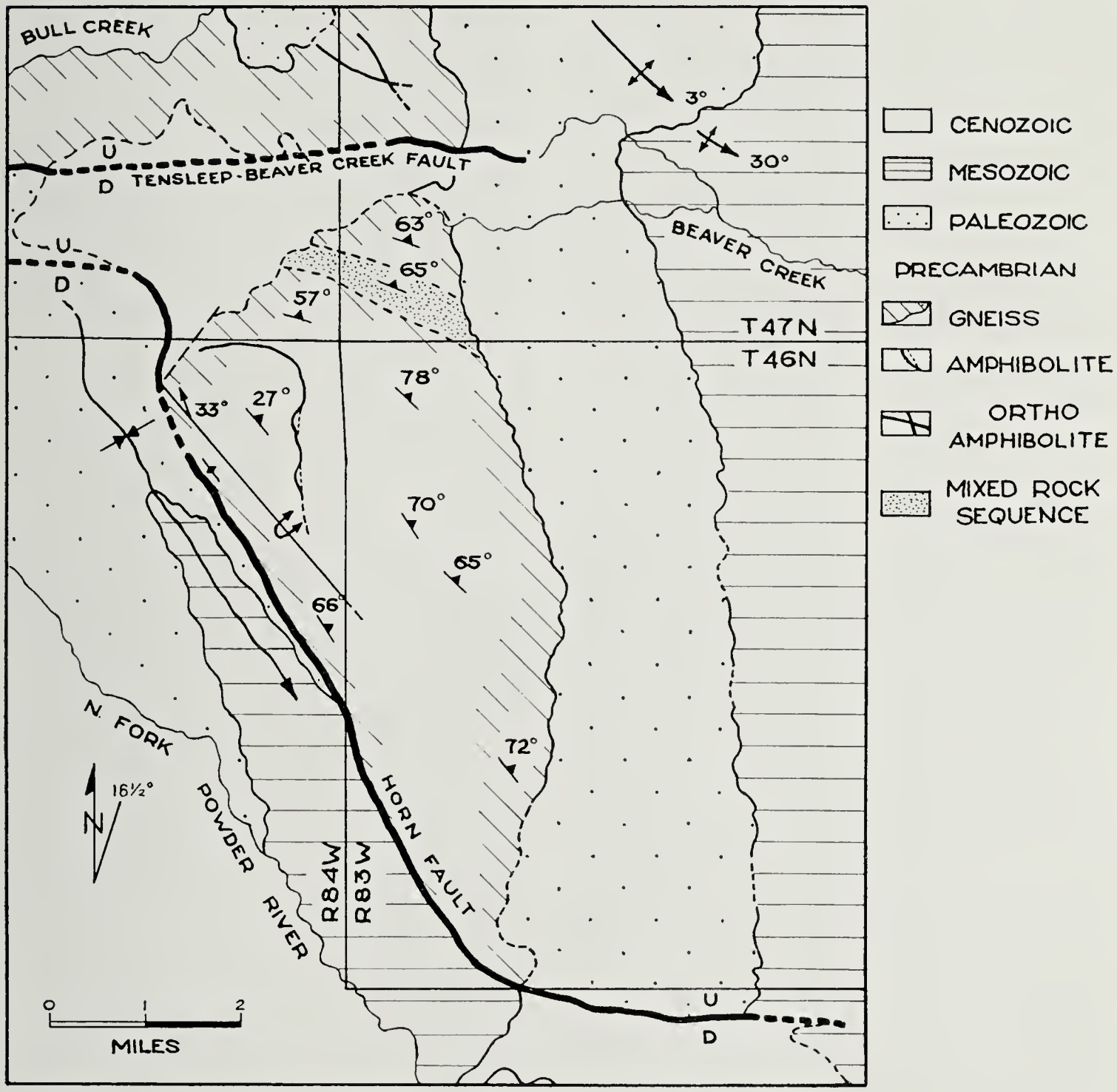

FIGURE 2.—Geologic map of the Horn area.

the western boundary but becomes a transverse fault along the southern boundary. On the east side of the uplift superjacent sedimentary rocks dip moderately eastward in continuity with the east flank of the central unit of the range. On the west, the sedimentary rocks have been dragged into an overturned syncline by movement on the Horn fault. The over-turned eastern limb of this syncline becomes the western

margin of the Horn, whereas its normal limb constitutes the east flank of the southern Bighorn unit.

General Description of Precambrian Rocks

A wide variety of Precambrian metamorphic rock types are exposed in what is referred to herein as the Horn gneiss complex, although granitic gneiss overwhelmingly dominates. Cross-cutting and conformable planar pegmatite bodies, irregular pegmatite masses and conformable lenses or pods of amphibolite commonly are associated with gneiss. Amphibolite characteristically occurs as small pods less than one or two meters thick; rarely is it found in planar units of mappable size. Pegmatites, too, are generally small scale features. Consequently, only a small proportion of the amphibolite and none of the pegmatite bodies are large enough to be shown on the geologic map and sections. Locally, biotite schist occurs and is gradational into biotite gneiss. The three rock types, granitic gneiss, pegmatite and amphibolite are well exposed. Other rare and poorly exposed rock types, include biotite schist, calc-silicate rock, marble, quartzite, quartz-hematite schist and garnetiferous rock. Some of these types would probably not have been discovered were it not for numerous test pits in the area.

Perhaps the most striking structural feature of these rocks is the conformability of their foliation or schistosity with lithologic contacts. With the exception of cross-cutting planar and irregular massive pegmatite, all rock types occur as interlayered, parallel or sub-parallel units. This conformability is disturbed locally, by complex minor folding, lensing, or boundinage effects. In some occurrences foliation may be obliterated by cataclasis, but the over-all parallelism of foliation and the various rock units remains a dominant characteristic.

Granitic Gneiss

Megascopic features. — The granitic gneisses are fine- to medium-grained rocks, the color of which ranges from light gray, to pink or tan, to dark gray. Several varieties were distinguished in in the field on the basis of texture and structure, irrespective of mineralogical composition. The most common variety is "normal" granitic gneiss having indistinct to well-developed foliation. Other varieties, listed in the order of estimated abundance, are: permeation gneiss, porphyroblastic gneiss, banded gneiss, augen gneiss, migmatitic gneiss and veined gneiss.

Mineralogical varieties include quartzo-feldspathic gneiss, quartz-plagioclase gneiss and feldspathic gneiss; each of these may contain biotite or hornblende or both as the mafic varietal(s). (In this paper, the term "quartzo-feldspathic" means that quartz, plagioclase, and potassium feldspar are present in significant amounts.) Biotite quartzo-feldspathic gneiss constitutes the most abundant variety. As the percentage of microcline decreases this variety becomes biotite quartz-plagioclase gneiss. Feldspathic gneiss (in which quartz is absent or minor) was found only in the vicinity of marbles and calc-silicate rocks. Contacts between mineralogical varieties are generally gradational, but some are sharp and parallel to foliation.

Banding in the gneisses is defined by alternating felsic and mafic layers and is accentuated by grains of biotite and hornblende lying with flakes or long axes in the plane of layering. The felsic layers generally consist of xenoblastic quartz, oligoclase, and microcline with minor amounts of either biotite or hornblende, depending upon which is the dominant mineral in the associated mafic-rich layers. Similarly, the mafic layers are biotite-rich, or more rarely, hornblende-rich, but some quartz and

feldspar usually are present. Some thin layers (less than 3 mm thick) may consist exclusively of hornblende, which tends to be more strongly segregated than biotite. Gneisses in which biotite is the dominant mafic varietal mineral tend to be less distinctly banded. Hornblende gneisses, on the other hand, show a stronger development of compositional layering; in the hornblende-rich layers the hornblende prisms often are aligned so as to define alineation in the plane of foliation. Within the felsic layers further segregation is sometimes present; quartz stringers and lenses and plagioclase-rich layers alternate with quartz-plagioclase-microcline layers. This type of segregation is developed commonly only in the leucocratic varieties of granitic gneiss.

Granitic gneisses show widespread mineral lineation which is marked by elongate aggregates of biotite or hornblende (streaks), or by the sub-parallel alignment of hornblende prisms or ellipsoidal biotite plates. The fact that hornblende prism alignment is more common than biotite lineation has been alluded to; the latter is seen only in areas of intense folding. Streaking and lineation involving hornblende alignment lie within the foliation plane and are developed commonly even where strong folding is not apparent. Foliation generally is more pronounced than lineation except in the axial zone of a major fold.

Mineralogy and textures. — The predominant gneisses show a wide variety of textural features and mineralogical types in thin section. Gneiss generally consists of approximately 90 percent quartz, plagioclase and microcline, with the remainder being biotite and/or hornblende plus accessories.

Quartz occurs characteristically as xenoblastic grains. Lenses and layers of quartz aggregates elongated parallel to foliation are common. Individual crystals of quartz embay plagioclase, but boundaries with other quartz grains are sutured. Strain effects are invariably present in the form of undulatory extinction and, less commonly, as deformation lamellae. Commonly, very fine (usually less than 0.1 mm), round quartz grains are enclosed by plagioclase and microcline.

Plagioclase feldspar is abundant in the granitic gneisses, having an antipathetic relation to potassium feldspar. Individual crystals are fine- to medium-grained, hypidioblastic, usually polysynthetically twinned and slightly altered. They appear cloudy or dusty as a result of the characteristic alteration to sericite, kaolinite and epidote. Sericite alteration often is preferentially developed along cleavage planes. Effects of stress in plagioclase are wavy, bent, or rarely, faulted cleavage and twin planes. Plagioclase composition ranges from An_5 to An_{23}, the mean composition from determinations made in 21 thin sections being An_{13}. Oligoclase may show albitic rims that are free of alteration. Myrmekite commonly occurs along contacts with microcline.

Potassium feldspar, ranging widely in percentage from sample to sample, is a constituent of nearly all samples. It exhibits a variety of textural relationships and unlike plagioclase and quartz shows no strain effects. Where present in minor amounts, it occurs interstitially and as fine-grained patch replacements in plagioclase (incipient replacement stage). In more advanced stages of replacement, potassium feldspar occurs either as disseminated medium-grained crystals or as microcline-rich layers. Coarse grained subhedral grains of microcline characteristically form the porphyroblasts in porphyroblastic gneiss. Most potassium feldspar shows well-developed grid twinning and is microperthitic, the strings or lenses of albite being in positions crystallographically controlled by the microcline host. Crystals of microcline are clear in contrast to the cloudy plagioclase. A thin section showing a ptygmatically folded microcline-quartz "vein" revealed that microcline is much more abundant in the gneiss adjacent to the "vein" than elsewhere in the gneiss.

Biotite is the usual mafic varietal, occurring as fine-grained, ragged plates or as fresh appearing lepidoblastic crystals. It cuts across plagioclase, is interstitial in quartzo-feldspathic material and has crystallized as flakes along shear planes. A thin section at right angles to the axial plane of a microfold shows that biotite flakes are oriented with their {001} cleavage parallel to the axial plane of the microfold. More commonly biotite is crystallized along shears parallel to the foliation. Absorption is strong (pleochroism X = straw yellow, Y = Z = dark brown) and pleochroic haloes often are well developed.

The alteration of biotite in the gneisses is far from simple. One thin section showed three distinct altera-

tions: (1) chlorite and magnetite, (2) bleached biotite and rutile needles, and (3) muscovite. The rutile needles are of interest because they may signify the release of TiO_2 upon retrograde transformation from a higher temperature assemblage (DeVore, 1955).

Hornblende is less abundant than biotite. It occurs characteristically as ragged prismatic to subhedral grains that are strongly pleochroic (X = pale greenish-yellow, Y = light green, Z = bluish-green or dark green). Some of the larger grains may contain quartz blebs and, less often, subhedral apatite. The characteristic alteration is to epidote, although biotite, chlorite and magnetite are not unusual.

Muscovite (including sericite), epidote, allanite, apatite, sphene and zircon are fairly common accessory minerals whereas magnetite, hematite, leucoxene, chlorite and garnet are less common. Muscovite occurs in sufficient amounts in some of the more sheared rocks to warrant the designation "two mica" gneiss. Such muscovite, having crystallized late, developed in part by replacement of biotite (it is often interlayered with biotite) and, in part, by forming lepidoblastic crystals oblique to foliation and cross-cutting quartz, feldspar and biotite. Sericite, epidote-group minerals, hematite, leucoxene and chlorite are alteration products whereas magnetite, apatite and sphene are associated with mafic varietals. In particular, sphene and especially apatite are associated with hornblende. Leucoxene alteration is observed only on sphene; hematite most commonly is on the margins of magnetite or in fractures emanating from magnetite. Expansion cracks usually are developed in plagioclase enclosing metamict allanite grains.

Pegamatite

Megascopic features. — Quartz-feldspar pegmatites are widespread. Most pegmatites contain both potassium feldspar and plagioclase; potassium feldspar is more abundant although a few pegmatites contain plagioclase to the exclusion of potassium feldspar. The ratio of feldspar to quartz is approximately 1:1 but often is higher, especially in pegmatites that are dominantly composed of microcline perthite and quartz. Biotite, magnetite and muscovite are coarse enough to be recognized in the field but other minor constituents were identified in thin section. A pegmatite may display a pink color owing to disseminated hematite but pinkish-gray, light gray or white colors are more common.

The pegmatites occur either as planar bodies or irregularly-shaped masses. Planar pegmatites may cut across or trend parallel to foliation. Conformable planar pegmatites often are quite thin, their thickness being measured in inches' whereas, cross-cutting pegmatites generally are thicker, sometimes exceeding 10 feet although most are less than 1 foot thick. Irregular, massive pegmatites appear to have engulfed the country rock inasmuch as they contain gneissic remnants. Planar pegmatites tend to have sharp contacts with the country rock whereas in irregular pegmatites boundaries are gradational. Cross-cutting planar pegmatites commonly exhibit very sharp contacts, fine-grained borders and coarse-grained central zones. Grain size is more uniform in the irregularly shaped pegmatite masses.

Mineralogy and Textures. — Coarse granoblastic texture predominates but locally graphic textures have developed. Some microcline perthite crystals are several inches long, and these often contain discrete quartz grains in cuneiform shapes or as blebs. In some cases quartz and feldspar form regular intergrowths of rods or plates. Generally, however, quartz and feldspar are xenoblastic. Cataclastic features are characteristic in quartz and plagioclase; in two examples mortar structure was observed.

Quartz is generally anhedral, presenting serrate or sutured borders to feldspar or itself forming a quartz mosaic. Cataclastic features, invariably shown by quartz, occur most commonly as undulatory extinction but deformation lamellae were noted also.

Plagioclase generally is dusty with sericite alteration. In many pegmatites bent plagioclase lamellae testify to pretectonic crystallization. Pegmatite plagioclase is generally more sodic than plagioclase of the gneisses (albite is characteristic of the pegmatites, oligoclase of the gneisses). Rims of clear, more sodic albite may be developed and myrmekite is observed on the border of potassium feldspar. In contrast to most plagioclase, microcline is clear and unstrained and usually perthitic.

Minor constituents may include biotite, magnetite, hematite, allanite, epi-

dote, clinozoisite, muscovite, hornblende, diopside, apatite, sphene, leucoxene, zircon, garnet, calcite, chlorite. Such constituents locally may reflect the mineralogy of the country rock: pegmatites in biotite gneiss contain biotite, pegmatites in hornblende gneiss contain hornblende, pegmatites in diopside gneiss contain diopside, pegmatites crossing amphibolites rich in sphene contain hornblende and sphene, etc.

Amphibolite

Megascopic features. — Amphibolites in the Horn area are black to dark grey or black and white, fine- to medium-grained rocks consisting principally of hornblende and plagioclase. Locally, coarse-grained patches consisting exclusively of hornblende have developed. In some occurrences a "salt-and-pepper" appearance is imparted because of scattered plagioclase. In a few exposures quartzo-feldspathic material forms conformable layers, lenses or streaks; in others it forms cross-cutting veins in the amphibolite. At one locality, amphibolite and quartz-feldspar veins are highly deformed. The over-all appearance suggests that the amphibolite was passively rolled in the surrounding, more plastic gneiss by the action of tectonic transport.

Amphibolite generally occurs in bodies too small to be mapped but with three principal habits: (1) as conformable planar layers; (2) as conformable pods or lenses; and (3) as cross-cutting planar bodies. Conformable planar amphibolite is abundant in the mixed rock sequence (Fig. 2). Only one conformable planar amphibolite was mapped but it has significance because it serves as a key horizon for structural determinations. Amphibolite lenses are widespread throughout the gneiss complex although they are more abundant in certain zones. These zones are parallel to foliation in the surrounding rocks, suggesting that the lenses once were connected. Only two cross-cutting planar amphibolite bodies were observed, both north of the Tensleep-Beaver Creek fault in the northeast part of Precambrian exposure.

Foliation and lineation are conspicuous. The former is marked by the arrangement of hornblende crystals in layers, or by the segregation of the minerals into light and dark layers, whereas lineation is often evidenced by aligned crystals of hornblende. Many of the massive appearing amphibolites show foliation, lineation, or both when examined in thin section.

Mineralogy and textures. — Typical amphibolite in thin section has fine- to medium-grained crystalloblastic texture. Hornblende is nematoblastic, either lineated or decussate. Plagioclase is usually xenoblastic, ranging in composition from An_{15} to An_{46} but sodic andesine is most common. Hornblende generally is altered to epidote or chlorite (usually penninite) or both, whereas plagioclase generally is altered to sericite. The hornblende to plagioclase ratio varies widely, but in most specimens it is slightly greater than one. Coarse hornblende commonly is poikiloblastic. Pleochroism of hornblende is commonly X = pale greenish-yellow, Y = light green, Z = bluish-green or dark green.

Minor consitituents include quartz, biotite, sphene, apatite, diopside, magnetite, microcline, allanite, and garnet.

Garnetiferous and related rocks associated with amphibolite. — Exposed near the center of the mapped, conformable amphibolite in Secs. 1 and 12, T. 46 N., R. 84 W. are some garnetiferous and related rocks, which indicate the composition of the rocks prior to metamorphism. Despite poor exposure, garnetiferous gneiss was traced discontinuously for over one-half mile as an apparently conformable zone (or zones) within the amphibolite body. Related rocks were observed in a more restricted area (SW¼ SE¼, Sec. 1, T. 46 N., R. 84 W). Associated with garnetiferous gneiss, but in much smaller amounts, are garnetiferous amphibolite, garnet-quartz-cummingtonite rock, tremolite schist and gedrite rock.

The garnetiferous gneiss has a rather complex mineral composition including quartz, calcic oligoclase, red-brown biotite, almandine, cordierite, sillimanite, magnetite, hematite and epidote and is similar to kinzigite of European petrologists. Foliation is defined both by subparallel orientation of lepidoblastic biotite flakes and by a tendency for the light and dark constituents to be segregated. This foliation is modified by large almandine garnet porphyroblasts (diameters range from a few millimeters to over two centimeters). Biotite foliae were thrust apart forcibly by the growing garnet, and quartz recrystallized in the pressure shadows. The garnet porphyroblasts are more noticeably poikiloblastic at their centers whereas their margins are relatively free of inclusions, suggesting that at a late stage of growth

the garnet was able to rid itself of foreign material. Both biotite and cordierite show pleochroic haloes. Some of the cordierite is altered to "pinite."

In sharp contact with garnetiferous biotite gneiss is a reddish-brown, hematite-stained garnet-quartz rock the texture of which superficially resembles that of a grit. Under the microscope a slightly strained, fractured, coarse-grained quartz mosiac is seen to surround and include xenoblastic, poikiloblastic, and fractured medium-grained almandine and lesser amounts of nematoblastic, fine-grained cummingtonite. Sub-parallel orientation, in discrete planes, of the prismatic cummingtonite gives the massive appearing rock a poorly developed lineation and schistosity.

Pale green and red mottled tremolite schist was collected in the locality of the garnet rocks. Schistosity results from planar arrangement of fine-grained, nematoblastic tremolite and poorly developed lineation is imparted by subparallel alignment of amphiboles. The green and red colors are due, respectively, to partial alterations of tremolite to chlorite plus talc and of magnetite to hematite.

Purplish-red gedrite rock also is associated with the garnetiferous biotite gneiss. The gedrite, an aluminous variety of anthophyllite, is asbestiform and largely altered to talc and lesser chlorite. Prisms of gedrite are oriented perpendicular to schistosity.

Amphibolites adjacent to the garnetiferous biotite gneiss also are garnetiferous. Foliation in these amphibolites is expressed as alternating layers of very fine- and fine- to medium-grained hornblende, quartz and andesine. The finer grained layers are $\frac{1}{16}$ - $\frac{1}{8}$ inches thick whereas the coarser grained layers may exceed $\frac{1}{2}$ inch. Such layers show a tendency to be hornblende-rich or hornblende-poor. Hornblende-rich layers are modified by almandine porphyroblasts which are rimmed by alteration to a complex of sericite, penninite, and epidote.

Marble and Calc-Silicate Rock

Carbonate rocks are exposed in a relatively narrow conformable zone (Fig. 2). Except for the northernmost exposure shown in Figure 2 they were investigated by Sargent (1960) and much of the following is taken from his report.

Foliated calcite marble. — This rock is generally dark blue to white, having fine- to coarse-grained granoblastic texture. The only consistent major constituent is calcite, although magnetite-ilmenite, diopside, apatite, garnet (andradite) and phlogopite occur locally in considerable amounts. Minor constituents include magnetite-ilmenite, diopside, apatite, garnet, phlogopite, epidote, tremolite, rutile, pyrite, chondrodite, allanite, zircon, quartz, chlorite, brucite and antigorite. Foliation is imparted by lepidoblastic phlogopite, nematoblastic tremolite or flaser structure in calcite. Deformation in the marble is evidenced by cataclastic effects in calcite, diopside and garnet.

Quartzo-feldspathic gneiss and pegmatite, calc-silicate rock, amphibolite, feldspathic rock and magnetite-ilmenite all form thin (usually less than a foot) interlayers, lenses or pods in the calcite marble. Commonly, the interlayers and lenses are gently warped. Contacts between foliated calcite marble and calc-silicate rocks are irregular and gradational, whereas contacts of calcite marble with the other rock types mentioned are usually sharp and regular.

Calc-silicate rock. — The calc-silicate rocks are best developed adjacent to or enclosed in marble. Major constituents are diopside and garnet (andradite); minor consituents include allanite, calcite, epidote-clinozoisite, hornblende, actinolite, magnetite, microcline, plagioclase (albite-oligoclase), sphene, chlorite, quartz and zircon.

Mixed Rock Sequence

An interlayered sequence of banded amphibolites, migmatitic quartzo-feldspathic schists and gneisses and impure quartzites was distinguished from its contiguous gneisses for the following reasons: (1) rocks in the sequence are much more highly differentiated than elsewhere in the gneiss complex, (2) banded amphibolites are much more abundant than elsewhere, and (3) cataclastic effects are more pronounced and better developed within the sequence than elsewhere.

These rocks were mapped as a unit and their distribution is shown in Figure 2. Table 1 gives the succession and thickness of the exposed rock units within the sequence. Youngest (?) rocks are at the top.

Amphibolite. — Banded amphibolite comprises nearly half of the exposed sequence. Amphibolite from the mixed rock sequence, in general possesses a better developed foliation than does amphibolite from other portions of the complex. The constituent minerals are variously proportioned in distinct layers. Typically, fine-grained, cataclastically granulated, andesine-quartz-hornblende layers alternate with medium-grained, hornblende-rich layers. Thin magnetite layers commonly are associated with hornblende-rich layers. Quartz and plagioclase are granoblastic, whereas hornblende is nematoblastic and may be aligned to yield a lineation. Some specimens, namely, the "feather amphibolites," contain aggregates of porphyroblastic hornblende which poikiloblastically includes quartz, plagioclase and hornblende, and which are flattened in decussate arrangement on foliation planes. Epidote-clinozoisite, zoisite and chlorite are alteration products of hornblende, and plagioclase is often altered to sericite or sericite and epidote; however, the alteration is not uniform. Some samples are fresh throughout, whereas others appear severely altered. Even within a single thin section, altered layers may alternate with relatively fresh layers.

Over-all mineralogy generally is like that of the previously described amphibolite elsewhere in the complex, although one specimen departs from the usual in that it contains abundant biotite and quartz; it might better be termed biotite-hornblende-quartz gneiss. Coarse, euhedral, black tourmaline was found within a quartz-feldspar segregation contained in an amphibolite from this mixed rock sequence.

Quartzo-feldspathic schist and gneiss. — These rocks are similar to the leptites of Scandinavian petrologists. Principal minerals are quartz, plagioclase, microcline and biotite but there is considerable variation in the proportions. At one extreme is quartz-biotite schist or biotitic quartzite. With more plagioclase the rock is called quartz-plagioclase schist. The name, quartzo-feldspathic biotite schist, is applied when microcline becomes a more important constituent. With increasing grain size, muscovite becomes prominent and the rocks may be called quartzo-feldspathic "two-mica" gneiss. Quartzo-feldspathic veins and lenses are abundant enough in some quartz-feldspar-biotite schists to warrant use of the term migmatite. Ptygmatic folding is well shown in some migmatites.

Textural relations of the constituent minerals are similar to those in the gneisses described previously. Microcline replaces plagioclase and muscovite replaces biotite, usually post-tectonically; however, in some examples from the mixed rock sequence, both microcline and muscovite are cataclastically deformed and fractured. In other cases the usual situation prevails, that is, clear, undeformed microcline replaces cloudy, deformed plagioclase.

Cataclastic features are abundant in these rocks. Undulatory extinction, bent plagioclase cleavage and twin units are nearly always present. In an extreme case, coarser quartz and feldspar grains form lenses around which granulated quartz and feldspar and micaceous material appears to flow in anastamosing streams. Such rocks are termed augen gneisses. In two locations phyllonites were observed. The massive appearing, resistant quartzo-feldspathic unit at the base of the sequence was called a "granite sill" in the field, but in thin section this rock shows a well-developed mortar structure. Thus cataclastic features are varied and abundant in the mixed rock sequence. *Banded quartz-hematite schist and impure quartzite.*— These rocks were found at two localities within the mixed rock sequence. The localities are stratigraphically separated by more than 300 feet, and only a few feet of quartz-hematite rock is poorly exposed in test pits at each place.

Banded quartz-amphibole rocks are associated with the ferruginous quartzites. The quartz-hematite schist consists of alternating $\frac{1}{8}$ - $\frac{1}{16}$ inch bands of quartz and hematite. Flakes of hematite are dispersed throughout the quartz bands, and small amounts of fine quartz (chalcedony?) occur within the hematite bands, but the segregation is marked. Grunerite is a minor constituent. Magnetite also occurs within the hematite bands.

A thin section of hematite-stained quartzite consisted of a fine-to medium-grained quartz mosaic in which very fine-grained, accessory hornblende, cummingtonite, garnet, biotite and magnetite are arranged in planes. The quartz grains have sutured boundaries, and their long dimension tends to parallel the planes of accessory minerals which are preserved to denote relict stratification.

Facies Classification and Conditions of Metamorphism

According to Read (1952, p. 7), traces of regional metamorphism may be preserved in resister rocks which may be used to reconstruct the metamorphic facies before granitization. Resister rocks are those extreme chemical types which require a great expenditure of energy and metasomatic action to convert them to granite. In the Horn area, resister rocks include amphibolite, marble, calc-silicate rock and quartzite. Because of the wide stability range of quartz, the quartzites are of little use in determining metamorphic facies; however, the mineral assemblages of amphibolite and carbonate rocks allow an accurate interpretation of metamorphic facies. The critical assemblages are as follows:

Amphibolite
- Hornblende-plagioclase-epidote (quartz-biotite)
- Hornblende-plagioclase-almandine-epidote (quartz-biotite)
- Hornblende-plagioclase-epidote (diopside-quartz)

Calcite marble (after Sargent, 1960)
- Calcite-diopside-phlogopite
- Calcite-diopside-tremolite (chondrodite-olivine)
- Calcite-tremolite-phlogopite (epidote-chondrodite-olivine)

Calc-silicate rock (after Sargent, 1960)
- Calcite-diopside-garnet-epidote (-tremolite-plagioclase)
- Calcite-diopside-epidote-plagioclase
- Diopside-hornblende-epidote-tremolite

These are believed to be equilibrium assemblages of the staurolite-quartz subfacies of the almandine amphibolite facies (Fyfe, Turner and Verhoogen, 1958, p. 229). Metamorphism in almandine-amphibolite facies covers a temperature range of perhaps 550° to 750° C., and pressures normally between 4,000 and 8,000 bars (Turner and Verhoogen, 1960, p. 553). The prevalence of amphiboles and micas indicates high water pressures.

Disequilibrium assemblages were also observed in the Horn area. High-grade metamorphic assemblages commonly show local or partial replacement by low-grade assemblages.

The following reactions have occurred:

plagioclase → epidote, sericite, kaolinite and more sodic plagioclase
diopside→amphibole
amphibole→chlorite epidote, biotite
cummingtonite→talc, chlorite
gedrite→talc, chlorite
grunerite→hematite, silica

Such reactions are believed to occur during cooling following the main high-temperature phase of metamorphism. The modern interpretation holds that these reactions are limited by the lack of water, which was driven away during the high-temperature phase. The necessary water could only become available by diffusion inward from some external source (Turner and Verhoogen, 1960, p. 505). In the Horn area minerals characteristic of a lower facies commonly occur in rocks strongly affected by cataclasis. This suggests that reaction rates were faster in cataclastically granulated materials and that, perhaps, the influx of the necessary water was guided by the granulated zones.

Petrogenesis

The occurrence of thin, conformable rock layers of undoubted sedimentary parentage (e.g., marble,

quartzite and banded quartz-hematite schist) intimately associated and intercalated with gneiss and amphibolite strongly suggests that the entire gneiss complex was initially of supracrustal origin. Schistosity, as well as mineralogical and lithological layering are conformable throughout the complex; cross-cutting pegmatites are the only exception. Furthermore, on the scale of the whole area, these features form a tightly folded, complex anticline. The ghost stratigraphy, revealed by resister rocks, and the large-scale lithologic architecture are difficult to explain unless these rocks represent transformed and partially granitized supracrustal rocks. A discussion of the origin of specific rock types follows:

Granitic gneiss. — Additional criteria favoring an origin by regional metamorphism and granitization of supracrustal rocks for the gneisses, in particular, include: (1) the occurrence of accessory rounded zircons in the gneiss, and (2) the banded nature of much of the gneiss.

Although detailed zircon studies were not attempted, observation of thin sections suggests that the rounded zircons are sedimentary relics. Ecklemann and Poldervaart (1957, p. 1242-1244) made detailed zircon studies of metamorphic rocks of the Beartooth Mountains which are similar in many respects to the rocks of the Horn area. They concluded (1957, p. 1250): "The high percentages of rounded zircons in all the rocks favor their sedimentary origin."

In regard to the genetic significance of banded gneisses, the following conclusions of Dietrich (1960, p. 99) are important:

> "The banding of nearly all banded gneisses reflects directly or reflects formation controlled by supracrustal layering.
>
> ". . . presently observable banding of many banded gneisses is probably hybrid in that after it was formed originally it was subsequently modified (commonly accentuated) as the result of differential anatexis, permeation, metamorphic differentiation, differential cataclasis, or some combination of such processes."

It is possible that the sedimentary parent of the quartzo-feldspathic gneiss was an argillaceous or pelitic rock. The chemical compositions of argillites and granites are not vastly different and, according to Misch (1949, p. 226) the addition of alkali and some silica will transform argillite into a rock of granitic composition. Evidence will be introduced later which supports this suggestion.

Pegmatite. — Ramberg (1952, p. 248) considers pegmatitization to be a phase of granitization; pegmatites observed in the Horn area conform to his genetic classification.

Most of the Horn area pegmatites are the replacement (non-dilation) pegmatites of Ramberg (1952). Criteria for recognition of replacement dikes were discussed by Goodspeed (1940). Evidence of a replacement origin for many of the Horn pegmatites includes: (1) lack of offset of the gneissic layers on either side of cross-cutting pegmatites (Fig. 3.), (2) relation of pegmatite-country rock mineralogy (p. 246), (3) external rim of ferromagnesian minerals (Fig. 4.), (4) undisturbed inclusions and relics of wall rock structure, and (5) variations in

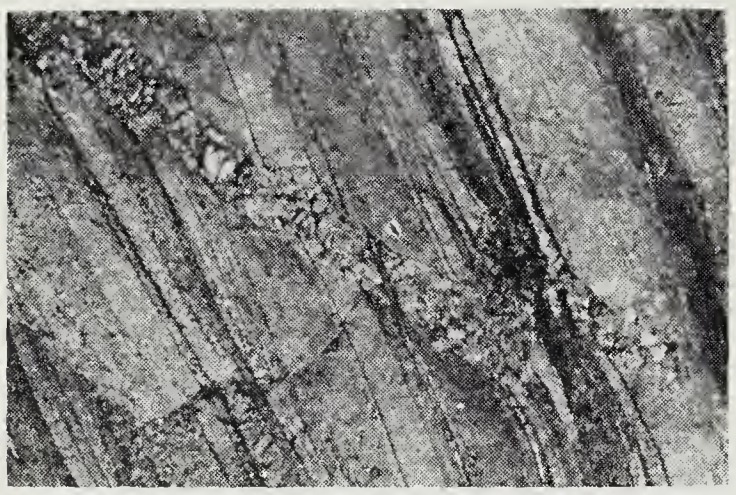

FIGURE 3. — Non-dilation pegmatite cutting across banded gneiss. Note the lack of offset in the gneissic bands.

FIGURE 4. — Pegmatite with basic rim of dark minerals that presumably represents Fe, Mg and Ca originally distributed in the space occupied by the pegmatite but now displaced by Si, K and Na.

FIGURE 5. — Pegmatite exhibiting variation in width, fine-grained boundaries, a coarse quartz-rich core, and reaction zone in the country rock.

width (Fig. 5.). The fact that several cross-cutting pegmatites have sharp, fine-grained borders and coarse-grained quartz-rich cores suggests that these characteristics are not exclusively those of magmatic dikes or else that these represent an extreme case where pegmatite fluids were evolved.

Amphibolite. — Ortho-amphibolite occurs only north of the Tensleep-Beaver Creek fault where two cross-cutting, intersecting amphibolite bodies were mapped. In addition to field relations, thin section study revealed blastophitic texture to further indicate a magmatic origin for these bodies. Thus, diabase(?) dikes were intruded prior to the regional metamorphism in the Precambrian rocks now exposed north of the Tensleep-Beaver Creek fault.

In the remainder of the area, conformability and foliation suggest para-amphibolite. From the available data the writer is unable to discern whether the amphibolite was derived from thoroughly recrystallized matatuffs or metasediments. It is possible that conformable amphibolite represents former sills or flows of mafic composition.

The absence of cross-cutting quartz-diabase, and quartz-gabbro dikes in the area south of the Tensleep-Beaver Creek fault is in sharp contrast to the situation further north in the Bighorns where these are prominent (Hoppin, 1961; L. O. Williams, personal communication).

Carbonate rock. — Sargent (1960, p. 111) suggests that the parent rock of calcite marble was a somewhat impure dolomitic limestone, and upon metamorphism the magnesium became fixed in phlogopite, diopside, chondrodite and forsterite. Misch (1949, p. 236-237) reports a similar occurence of thin marble layers in

a regionally metamorphosed terrain of the northwest Himalayas.

The calc-silicate rocks include types intermediate in composition between marble and quartzo-feldspathic gneiss. Sargent (1960, p. 108) suggests that they may represent calcereous argillites or argillaceous limestones (dolomites).

Garnetiferous rock. — The garnetiferous rocks, being conformably enclosed in an amphibolite "resister", were well shielded from alkali metasomatism. Thus the garnetiferous gneiss may reveal the chemical composition of the sedimentary rock prior to granitization. The pelitic mineral assemblage described for the garnetiferous gneiss (kinzigite) is strong evidence supporting the notion that the quartzo-feldspathic gneisses were derived from argillaceous rocks. Alkali metasomatism of argillites will form potash and soda feldspars with pure aluminum silicates becoming an unstable phase.

The gedrite and cummingtonite rocks associated with the garnetiferous rocks probably resulted from local Mg-Al metasomatism.

Banded quartz-hematite schist. — Accessory hornblende, cummingtonite, garnet and magnetite (arranged in planes) have been described previously and interpreted as marking relict stratification planes in quartzite. These accessories are believed to represent, not relict heavy minerals, but ferruginous, calcareous, aluminous impurities in a very fine-grained siliceous sediment (chert or siliceous lutite). The quartzite and associated quartz-hematite schists are believed to have originated in the following way.

High-grade regional metamorphism of chert-siderite, chert-greenalite or intercalated Fe, Mg —rich clay and siliceous lutite yielded a quartz-magnetite-grunerite layered rock. Later oxidation by hydrothermal(?) solutions caused magnetite to go to hematite and grunerite to go to hematite plus silica. The occurrence of a chalcedony vein with combstructure in a hematite-rich band is further indication of late hydrothermal(?) action. The effects of the oxidizing, hydrothermal(?) solutions were very minor, being recognized only in these rocks. The age of this event can only be given as post-metamorphism.

Summary of petrogenesis. — (1.) Supracrustal rocks, dominantly argillaceous but locally siliceous, calcareous, magnesian or ferruginous, were deposited. Volcanic layers probably were intercalated with sedimentary layers. (2.) Regional metamorphism with synkinematic neocrystallization and recrystallization in amphibolite facies formed complexly folded high-grade metamorphic rocks. (3.) Alkali metasomatism was a late phase of the regional metamorphism and culminated in pegmatitization. Such rocks as amphibolite, marble, calc-silicate rock and quartzite were relatively unaffected by this metasomatism. (4.) The last phase of regional metamorphism selectively formed rocks of greenschist facies. The reactions are believed to have been influenced by such factors as pH_2O and pCO_2 which in turn were controlled by cataclastic features.

TABLE 1. — Succession and thickness of rock units in the mixed rock sequence.

ROCK TYPE	THICKNESS (feet)
Banded amphibolite	35
Banded "feather amphibolite"	12
Biotitic quartzite	12
Conformable quartz-plagioclase pegmatite	3
Micaceous quartzite with lenses of pegmatitic quartz, albite and muscovite	14
Garnetiferous quartz-plagioclase-biotite schist	6
Banded amphibolite	17
Quartzo-feldspathic biotite schist.	42
"Feather amphibolite"	10
Quartz-plagioclase-biotite schist.	15
Covered	6
Quartzo-feldspathic biotite schist.	5
Covered	36
Banded amphibolite interlayered with chlorite schist	300
Coarse biotite-oligoclase rock with minor almandite, quartz plagioclase biotite schist and banded quartz-hematite schist (poorly exposed)	30
Micaceous quartzo-feldspathic gneiss with minor interlayers of banded amphibolite	120
Quartz-biotite amphibolite	18
Micaceous quartzo-feldspathic gneiss interlayered with quartz-biotite schist	76
Covered	126
Quartzitic rocks including banded quartz-hematite schist, and banded quartz-amphibole, hornblende, cummingtonite-grunerite, actinolite (?) rock	8
Covered	116
Quartzo-feldspathic rock with mortar structure	1
	1,018

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DIGITARIA SANGUINALIS IN SOUTH AMERICA

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ABSTRACT.—The distribution of the north temperate species *Digitaria sanguinalis* (L.) Scop. is extended to southern South America with its tropical equivalent, *Digitaria adscendens* (HBK.) Henrard, occurring further north. This study also reveals that there is a strong correlation between the average winter temperature and the distribution of these two species. Furthermore, in the region of overlap an occasional intermediate plant is found.

At present the common crabgrass *Digitaria sanguinalis* (L.) Scop. is considered to be restricted to the temperate regions of the northern hemisphere and to southern Africa with its morphological similar counterpart, *D. adscendens* (HBK.) Henrard, occurring in the tropical and subtropical regions (Henrard, 1950). Recently a few collections of *D. sanguinalis* from Argentina were found among specimens of *D. adscendens*. Due to this distribution a more thorough study seemed necessary to determine whether a chance introduction of *D. sanguinalis* had occurred or whether a well established population existed in southern South America.

MATERIALS AND METHODS

The basis of this study was herbarium material ,and more than 100 collections from South America were examined. The herbarium specimens were separated into two groups using the characteristics outlined by Henrard (1950). Finally, the data were arranged in the form of a scatter diagram, and the collections examined were plotted on a map to show the geographic distribution.

DISCUSSION RESULTS

Morphological analysis. In general growth habit, *Digitaria sanguinalis* and *D. adscendens* are strikingly similar. *Digitaria sanguinalis*, however, has a second glume half as long as the spikelet, spicules on the nerves of the sterile lemma, and cauline leaves heavily pubescent on both surfaces with papillose-based hairs. Typical *D. adscendens*, in contrast, has a second glume that is about two-thirds to three-fourths as long as the spikelet, no spicules and glabrous cauline leaves.

A preliminary morphological examination indicated that the above-mentioned characters could be used to separate these two species in South America. The data derived from this study were plotted on a scatter diagram similar to that described by Ebinger (1962). Two definite groups were found on the graph, one representing *Digitaria adscendens*, the other *D. sanguinalis*. Between these two groups were plants intermediate with respect to the length of the spikelets and second glume. In this part of the graph, the specimens differed completely in the traits of spicules and leaf pubescence. Such plants probably represent hybrids between the two species.

Geographic distribution. The results of the morphological analysis were plotted on a map (Figure 1)

BRAZIL
ARGENTINA
2nd glume less than 1.6mm long
2nd glume more than 1.6mm long
spicules present throughout spikelet
spicules present at tip of spikelet
cauline leaves very pubescent
cauline leaves slightly pubescent

FIGURE 1.—Distribution and variability of *Digitaria adscendens* and *D. sanguinalis* in southern South America.

to determine whether each species had a distinct geographic range. On this map each circle or square represents a single specimen. A square indicates that the length of the second glume was less than 1.6 mm long while a circle indicates that the second glume was longer than 1.6 mm. A long bar radiating to the left indicates that there are spicules all along the nerves of the sterile lemma, while a short bar indicates that a few spicules are found on the lemma nerves near the tip. A long bar radiating to the right indicates that the cauline leaves are pubescent throughout on the upper and lower surfaces, while a short bar indicates that a few hairs are present, usually on the lower surface near the base of the blade.

It seems significant that *Digitaria sanguinalis* (represented by squares with two long bars) is common

throughout Uruguay, central Argentina and all of Chile while *D. adscendens* (represented by circle without bars) is very common further north. Numerous specimens of this species were found in Brazil, Paraguay, Bolivia, and northern Argentina. The circles with bars radiating from them and the squares without bars or short bars show various degrees of intermediacy between the two species.

Most of these intermediate types are similar to *D. adscendens,* differing only in having papillose-based hairs on the culm leaves (line radiating to the right). These plants which are common in northern Argentina, southern Brazil and Urguay may indicate gene flow between the two species. However, due to the total exclusion of *D. sanguinalis* in some of these areas, it is also possible that this character represents normal variation within *D. adscendens.* It should be mentioned that the frequency of pubescent culm leaves is less in the members of this species found in northern South America. The remaining characteristic (spicules) seems to indicate introgression of characters between the two species. Plants with this characteristic are almost exclusively restricted to the geographic region of overlap, which includes Uruguay and the central and northern part of Argentina. Such specimens are difficult to place taxonomically and probably represent hybrids.

Factors responsible for species distribution. Because the two species can be separated and since each has a distinct geographic range, an attempt was made to determine what factors were responsible for this distribution. The only phenomenon with which geographic distribution could be correlated was temperature. The northern limit of *Digitaria sanguinalis* in South America is the region in which the average July temperature is about 45° to 50° F. Byers (1959) shows these isotherms extending through southern Uruguay and central Argentina which is the region in which the intermediate plants were found. Although these isotherms also extend through central Chile, no specimens of *D. adscendens* or intermediate plants were found in the northern part of this country.

It is interesting to note that the distribution of *Digitaria adscendens* and *D. sanguinalis* in North America is correlated with the 45° to 50° F. January isotherms. On a distribution map of these two species (Ebinger, 1962), *D. sanguinalis* is found to the north of these isotherms while *D. adscendens* occurs to the south. Along the region of overlap many intermediate plants are found.

No attempt was made to determine the distribution of these two species in Africa. Chippindall (1955), however, mentions that *D. adscendens* is confined to the north and eastern parts of the Union of South Africa while *D. sanguinalis* is found in the southern and western regions. He further states that a few plants from the north-eastern Cape are somewhat intermediate between these two species. The mean surface isotherm map (Byers, 1959) shows that the average July temperature for South Africa is between 50° and 60° F., much warmer than that found where *D. sanguinalis* oc-

curs in the western hemisphere. The map further shows that the temperatures in the eastern and northern parts of South Africa are warmer by almost 10 degrees than those found in the southern and western parts. This temperature variation is probably responsible for the distribution of *D. sanguinalis* in this part of South Africa.

Conclusion

There is a strong correlation between the 45° and 50° F. isotherms and the distribution of *Digitaria sanguinalis* and *D. adscendens* in South America. *Digitaria adscendens* occurs to the north of these isotherms and *D. sanguinalis* to the south. In the region of overlap (between the 45° and 50° F. isotherms) some intermediate plants occur. Both parental species are also common in the overlap region which shows that, in spite of probable hybridization, there has been little tendency toward the amalgamation of these two species. This indicates that at least a partial sterility barrier exists, or that other factors are preventing excessive hybridization and backcrossing.

Acknowledgments

Sincere thanks are expressed to Dr. John R. Reeder, Yale University, New Haven, Connecticut, for suggesting the original problem. Thanks are also expressed to the numerous herbaria for the loan of the herbarium material used in this study.

Representative Specimens

Digitaria adscendens (HBK.) Henrard

ARGENTINA: *A. L. Cabrera 1086; A. T. Hunziker 492; M. M. Job 699; P. Jorgensen 1260; F. Kuntz 8910; C. Lizer 4678; M. R. Malvarez 552; L. Monetti 1500, 1801; C. A. O'Donell 185; Tito & Ybarrola 1884, 2905; S. Venturi 2153, 2662, 2796, 3829, 7140.*

BOLIVIA: *Britton & Rusby 264; O. Buchtien 418, 444, 3654, 5318, 6439, 6440, 7126; A. S. Hitchcock 22606, 22839; H. H. Rusby 245, 675; J. Steinbach 1978, 6839, 6848, 7057.*

BRAZIL: *Agnes Chase 10066, 10168, 10756, 11311; F. C. Hoehne 241; C. Jürgens 3; C. A. Lindman 1335; F. C. Paulo 241; B. Rambo 30771, 40660, 40979; E. Raupp 125, 174, 184, 217; Reitz & Klein 698, 3104; B. Rosengurtt 3303, 3308, 3350, 3420; Smith & Reitz 9744; A. P. Viegas 2150.*

PARAGUAY: *P. Jorgensen 3548, 4100; T. Rojas 12597, 13003, 13842, 13863; B. Rosengurtt 5498, 5625, 5752.*

URUGUAY: *W. Herter 18822; B. Rosengurtt 4557, 5141, 5707.*

Digitaria sanguinalis (L.) Scop.

ARGENTINA: *O. Paci 652; R. A. Ruiz Leal 2839; A. G. Schulz 6089.*

CHILE: *O. Buchtien 109; H. Gunckel 5811; A. S. Hitchcock 22936; L. Jorquera (18 Feb 1949); C. Joseph 934, 2337, 3361; R. A. Philippi 376.*

URUGUAY: *Berro 3311, 5033, 7322, 7872; W. Herter 68142; Eva M. March 52; B. Rosengurtt 1508, 7716.*

Specimens Intermediate Between the Two Species

ARGENTINA: *O'Donnell & Rodriquez (12 Mar 1944); J. M. Rodriquez 39157; T. Stuckert 69.*

BRAZIL: *Reitz & Klein 2783.*

URUGUAY: *W. A. Archer 4976; W. Herter 99487.*

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ISOLATION OF PROTOTROPHIC HYPHAL TIPS FROM SPECIFIC HETEROCARYONS IN *CEPHALOSPORIUM MYCOPHILUM*

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ABSTRACT. — Specific combinations of mutant strains in *Cephalosporium mycophilum* form "balanced" heterocaryons from which heterocaryotic and prototrophic hyphal tips may be isolated. The competitive advantage exhibited by somatic diploid mycelium in previously investigated "unbalanced" heterocaryons was also observed in the "balanced" heterocaryons suggesting ineffective complementation within both "balanced" and "unbalanced" heterocaryons. The results further suggest some functional difference between genetic elements combined in a single nucleus and the same genetic elements within separate nuclei, but combined into a single cytoplasmic unit. How nuclear fusion might enhance complementation in this species is not obvious.

It has been reported previously that it was not possible to isolate prototrophic hyphal tips from specific heterocaryons in *Cephalosporium mycophilum* (Cda.) Tubaki (Tuveson and Coy, 1963; Tuveson 1964). With a single exception, hyphal tips isolated from the heterocaryons and transferred to complex medium were homocaryotic for one of the nuclear components in the heterocaryon. Hyphal tips from the exceptional heterocaryon (HET VI-C) when transferred to complex medium were homocaryotic for one or the other of the component nuclei in the heterocaryon. However, not a single heterocaryotic hyphal tip was isolated from this exceptional heterocaryon. It was postulated that the ability to isolate heterocaryotic hyphal tips from this exceptional heterocaryon may simply have been a result of the small number of tips analyzed. This paper presents evidence which suggests that heterocaryotic and prototrophic hyphal tips can be isolated from HET VI-C when a sufficiently large sample of tips is isolated. Further, evidence is presented showing that heterocaryotic and prototrophic hyphal tips can be isolated from another heterocaryon (HET XI-C) which differs from HET VI-C in that one of its components has an additional nutritional requirement.

MATERIALS AND METHODS

The source of the wild type culture, the medium used and the methods for the induction, isolation and characterization of mutants have been presented (Tuveson and Coy, 1961). The mutant strains used in this investigation and in previous investigations (Tuveson, 1964) were: adenineless, methionineless, orange (-ade, -met, ora); cysteineless, leucineless, green (-cys, -leu, gr); cysteineless, leucineless, argininеless, green (-cys, -leu, -arg, gr); argininеless, orange (-arg, ora). Retesting of the arginine requirement in the -arg, ora strain revealed that this mutant also responded to ornithine or citrulline. The arginine requirement in the green strain (-cys, -leu, -arg, gr) was satisfied specifically by arginine indicating that the arginine requirements in the orange and green strains involved different genes.

Methods for the synthesis of heterocaryons and "mat controls" have been described (Tuveson and Coy, 1961; Tuveson, 1964).

The input proportions of the two nuclear types for the heterocaryons were

determined by viable counts after initial adjustments based on haemocytometer counts. A mean viable count was calculated from ten replicates.

The concentrations of supplements added to minimal medium for the identification of the nutritional requirements of strains and techniques for the isolation of hyphal tips have been presented (Tuveson and Coy, 1961; 1963).

The methods used for the identification of the nutritional requirements of the colonies derived from hyphal tips were identical to those described previously (Tuveson, 1964).

All cultures were incubated at 25 ± 2C.

Experimental Results and Discussion

In previous experiments, it had been demonstrated that it was not possible to isolate prototrophic hyphal tips from HET IV-C (Tuveson and Coy, 1963; Tuveson, 1964). As a check on previous experiments, hyphal tips were isolated from mycelial mat fragments of HET IV-C (-ade, -met, ora + -cys, -leu, -arg, gr) growing on minimal medium (Table 1). As was expected, all the hyphal tips isolated and transferred to complex medium were homocaryotic for the orange component (-ade, -met, ora). None of the tips transferred to minimal medium formed colonies after 28 days of incubation. These results substantiate previous observations. Clearly, maintaining the mutant stocks for three years in the laboratory had not resulted in any significant alterations of these stocks.

Hyphal tips were isolated from mat fragments of HET VI-C (-arg, ora + -cys, -leu, gr) after 5 and 13 days of incubatiaon on minimal medium. The results are in substantial

Table 1.—Growth of Hyphal Tips from Heterocaryons Grown on Minimal Medium

Heterocaryon and component strains	Input nuclear ratio[a] orange component : green component	Age in days of colony from which tips were isolated	Medium to which isolated	Total no. of tips	No. of colonies	Genetic Constitution
IV-C						
-ade, -met, ora + -cys, -leu, -arg, gr	2 : 1	13	complex	25	25	-ade, -met, ora
			minimal	25	0	—
VI-C						
-arg, ora + -cys, -leu, gr	7 : 1	5	complex	26	26	25 -cys, -leu, gr 1 heterocaryon
			minimal	24	0	—
		13	complex	50	49	30 -cys, -leu, gr 14 -arg, ora 5 heterocaryons
			minimal	50	2	2 heterocaryons
XI-C						
-arg, ora + -cys, -leu, -arg, gr	1 : 1	13	complex	27	25	7 -cys, -leu, gr 14 -arg, ora 4 heterocaryons
			minimal	25	2	2 heterocaryons

[a]Input nuclear ratios are based on viable counts.

agreement with those reported previously (Tuveson, 1964) with the notable exception that a single and five heterocaryotic hyphal tips were observed among the tips transferred to complex medium from 5 and 13 day old colonies respectively. In addition, two of the tips isolated from the 13 day old cultures and transferred to minimal medium formed small colonies after 21 days of incubation on minimal medium. These colonies were transferred to fresh minimal medium plates to prevent desiccation and incubated for 21 additional days at which time it was possible to analyze the conidia produced by the colonies. Both nuclear components were recovered among the conidia establishing that these colonies were heterocaryotic and prototrophic. HET VI-C differs from the five heterocaryons previously investigated in that when growing on minimal medium one of the nuclear components does not predominate resulting in the colonies developing a homocaryotic periphery. Ineffective complementation had been postulated to account for the results with the five previous heterocaryons in which one of the nuclear components predominated in the heterocaryons growing on minimal medium (Tuveson and Coy, 1963; Tuveson, 1964). It had been postulated that as a result of ineffective complementation, the heterocaryons became homocaryotic at the periphery, stopped growing following which fans of somatic diploid mycelium emerged from the heterocaryotic colonies. When HET VI-C was grown on minimal medium, both component strains were easily recoverable among the hyphal tips isolated from a 13 day old colony. In contrast to the five previously investigated heterocaryons, HET VI-C appeared to be a "balanced" heterocaryon (neither nuclear component predominates in the heterocaryotic mycelium). Despite the fact that HET VI-C appeared to be a "balanced" heterocaryon, somatic diploid fans emerged from these colonies when growing on minimal medium in a manner equivalent to that observed with other heterocaryons in this species. It is also of interest to note that heterocaryotic hyphal tips isolated from HET VI-C and growing on minimal medium required six weeks to form a colony large enough for the isolation of conidia for the re-isolation of the original component homocaryons. Heterocaryotic hyphal tips isolated from HET VI-C and growing on complex medium required 18-21 days to form colonies large enough such that conidia might be isolated to recover the original component strains. This observation suggests that complementation between the component strains in HET VI-C is ineffective (or inefficient) although it would seem to be a "balanced" heterocaryon. It must be concluded that complementation is much more effective when the component nuclei have fused to form a somatic diploid rather than when unfused nuclei are present in the same cytoplasmic unit (heterocaryon). Roberts (1964) has reported that complementation for certain sorbitol markers in *Aspergillus nidulans* differs in heterocaryons and somatic diploids. These observations suggest some functional significance

to the association of genetic elements within a single nucleus as opposed to the same genetic elements in separate nuclei within a single cytoplasm. How fusion of nuclei might enhance complementation is not obvious.

The results obtained with HET XI-C were equivalent to those obtained with HET VI-C (Table 1). The only difference between these two heterocaryons was that the green component in HET XI-C carried an additional nutritional marker (-arg). Clearly, the additional marker had little influence on the complementation relationship between the components.

The results reported here differ from those reported previously (Tuveson and Coy, 1963; Tuveson 1964) in that it was possible to find specific combinations of mutant strains which when incorporated into heterocaryons allowed for the isolation of prototrophic hyphal tips. This leads to the conclusion that heterocaryons may have differing properties depending, in very large part, on the mutants employed in the investigation. Recently, it has been reported that the yield of prototrophic hyphal tips from specific heterocaryons in the plant pathogenic fungus, *Ascochyta imperfecta*, is dependent on the combination of mutants used to synthesize the specific heterocaryons (Sanderson and Srb, 1965). It would appear that conclusions may be drawn concerning the properties of specific heterocaryons within a species, but it seems doubtful that general conclusions concerning heterocaryosis as a phenomenon can be drawn from the examination of a limited number of heterocaryons within a species.

Acknowledgment

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CELLULAR RESPIRATION AND PHOSPHORYLATION DURING COLD EXPOSURE IN RATS

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ABSTRACT. — The effect of cold exposure (4 weeks at 2 to 5°C) on the oxidative phosphorylation and respiration of liver mitochondria and liver homogenates in rats was studied. The studies were made polarographically using the Clark type oxygen electrode. Respiration was measured with added exogenous substrate (succinate), exogenous substrate plus ATP, and exogenous substrate plus ADP. No alterations were observed in mitochondria from cold-exposed rats. The ADP:O ratio was significantly lower and the succinate-ADP respiratory rate was significantly higher in homogenates from cold-exposed rats.

The experimental work described here was designed to investigate in detail the effect of cold exposure on certain of the tissue metabolic parameters that characterize cold acclimation. The pursuit of this study was encouraged by the conflicting results previously reported in measuring these parameters. For example, Smith and Fairhurst (1958) suggested that oxidative phosphorylation ,that is, the conversion of ADP (adenosine diphosphate) into ATP (adenosine triphosphate), which is normally coupled to cellular respiration, may become partially uncoupled in the mitochondria of cold-exposed animals. Several studies of oxidative phosphorylation using liver homogenates and unwashed liver mitochondria from cold-exposed rats tend to support this hypothesis (Hannon, 1959; Panagos et al., 1958; Lianides and Beyer, 1960). Other studies using liver mitochondria from cold-exposed rats have failed, however, to demonstrate an uncoupling of oxidative phosphorylation (Patkin and Masoro, 1960; Chaffee et al., 1961; Frehn and Anthony, 1962.)

In an attempt to explain these apparently contradictory results, Patkin and Masoro (1960) suggested that oxidative phosphorylation, a mitochondrial event, may be regulated by extra-mitochondrial factors. This suggestion was based on the finding of Smith (1960) that an uncoupling of oxidative phosphorylation in cold-exposed rats occurs only in systems where other cell components are present in addition to the mitochondria. Thus, it is presumed that these extra-mitochondrial factors may be removed on preparing washed mitochondria (Smith, 1960).

Aldridge and Stoner (1963) measured oxidative phosphorylation in cold-exposed rats, using both washed and unwashed liver mitochondrial preparations. In contrast to the finding of Smith and Fairhurst (1958), however, they found that the liver mitochondria from these cold-acclimated rats did not differ from normal rats in their P:O ratios (number of moles of ADP phosphorylated per gram atom of oxygen consumed) in either the washed or unwashed preparations.

In addition to the studies on oxidative phosphorylation, additional investigations have suggested that augmented rates of tissue oxygen consumption may contribute toward increased non-shivering thermogenesis during cold exposure (Hannon, 1960). In support of this suggestion, some investigators using tissue homogenates or tissue slices (Hannon, 1958; Clark et al., 1954; You and Sellers, 1951) have found an increased rate of tissue oxygen consumption in cold-exposed rats. Others, using mitochondrial preparations, have failed to show such an increase in the rate of tissue respiration (Smith and Fairhurst, 1958; Chaffee et al., 1961; Frehn and Anthony, 1962). Aldridge and Stoner (1963) observed no increase in oxygen consumption in either washed or unwashed liver mitochondrial preparations from cold-exposed rats.

It is becoming increasingly evident that the *in vitro* determination of the metabolic responses of cold-exposed animals is markedly influenced by the method of tissue preparation. The present study was, therefore, undertaken with the aim of attempting to help clarify the conflicting reports by further investigating the differences between liver mitochondrial and homogenate respiration during cold exposure in rats.

Materials and Methods

Ten adult female strain CFE (Carworth Farms) rats were exposed to a continuous cold environment of 2 to 5°C for 3 to 5 weeks. These animals (plus 10 controls maintained at an ambient temperature of 24° ± 1°C) were used to study the effect of cold on liver mitochondrial respiration. A second group of six rats was exposed to cold for 4 weeks to study the effect of cold on liver homogenate respiration. Again, six controls were maintained at ambient temperature.

Washed mitochondria were prepared according to the method described by de Duve et al., (1955). The entire procedure for the isolation of the mitochondria was carried out in a cold room (1 to 2°C). Animals were killed with a sharp blow on the head, and the liver quickly removed and placed into an ice-cold isolation medium. The isolation medium contained 225mM mannitol, 75 mM sucrose, and 0.1 mM EDTA. Homogenization of the tissue was carried out by forcing a rotating Teflon pestle to the bottom of the grinding tube.

The tissue used for the study on rat liver homogenate respiration was prepared by subjecting the homogenized tissue suspension to slow speed centrifugation (500 x g for 8 minutes) in order to remove erythrocytes, nuclei and unbroken cells. Measurements of respiration and phosphorylation were made polarographically, using the rotating oxygen electrode as originally described by Chance and Williams (1955) as well as the Clark oxygen electrode as described by Strickland et al., (1960). The reaction medium contained 45mM mannitol, 15 mM sucrose, 40 mM KC1, 20mM $MgCl_2$, 20 mM phosphate buffer, pH 7.3, and 10 mM succinate. Ten microliters of 0.05 M ADP were added to determine the ADP plus substrate respiration rate and efficiency of oxidative phosphorylation. In addition, 20 microliters of 0.1 M ATP were added to the homogenates during the reaction to determine the substrate plus ATP rate of respiration.

Results and Conclusions

The results of the study of the effect of cold exposure on respiration and P:O ratios in washed liver mitochondria are shown in Table 1. Respiration values represent X ± S.E. in μM O_2/second/mg. of nitrogen. The R_s value represents the respiratory stimulation with ADP. Succinate was used as a substrate. It is evident from these data that

TABLE 1.—Effect of cold (3-5 weeks at 2-5°C) on exogenous substrate respiration and phosphorylation in rat liver mitochondria.

Rats	N	Succinate	Succinate plus ADP	R_s	P:O
Control	10	0.83 ± .04	6.11 ± .20	7.4	1.67 ± .04
Cold-exposed	10	0.79 ± .03	5.95 ± .20	7.6	1.62 ± .03

the P:O ratio remains unaltered in washed mitochondria from cold-exposed rats. Likewise, it appears that the exposure of rats to cold has no effect on the succinate respiration of liver mitochondria. In addition, the R_s values shown in Table 1 indicate that ADP stimulates respiration in the cold-exposed group to the same extent as in the controls.

To determine whether a supression of P:O ratios in cold-exposed rats occurs when other cell components are present in addition to the mitochondria, studies were also made on homogenates. These data are summarized in Table 2. In contrast to the results obtained with washed liver mitochondria, it was found that the P:O ratios are significantly decreased in liver homogenates from cold-exposed rats.

The measurements which were made on liver homogenate respiration are also shown in Table 2 and include: (a) substrate (succinate) respiration, (b) substrate plus ADP respiration, and (c) respiration in the presence of excess substrate plus ATP. Previous work has shown that ATP stimulates homogenate respiration in the presence of excess exogenous substrate (Ziegler et al., 1963). This stimulation probably is due to an increased ADP concentration resulting from the dephosphorylation of the added ATP. The ratio of the substrate-ATP rate of respiration to the substrate rate of respiration provides a measure of the ATPase activity of the cells.

The results suggest that homogenate respiration in the presence of excess substrate (succinate) is unaffected by cold exposure. Likewise, exposure to cold does not appear to cause any alteration in the ATPase activity of the liver tissue. This is indicated by the fact that homogenates from control rats are stimulated by addition of ATP to the same extent as are the cold-exposed rats. These results are in agreement with previous reports that ATPase activity does not change during cold exposure (Hannon, 1959).

The data in Table 2 also show that the addition of ADP to the tissue homogenates stimulates sub-

TABLE 2.—Effect of cold (4 weeks at 2-5°C) on exogenous substrate respiration and phosphorylation in rat liver homogenates.

Rate	N	Succinate	Succinate plus ATP	Succinate plus ADP	R_s	P:O
Control	6	0.28 ± .01	0.33 ±.01	0.85 ± .03	2.6	2.02 ± .02
Cold-exposed	6	0.28 ± .01	0.34 ±.01	1.04 ± .03*	3.1*	1.74 ± .06*

* $P < .01$

strate respiration to a greater extent in the cold-exposed animals than it does in the controls. Thus, the maximum rate of tissue homogenate respiration (i.e., respiration in the presence of excess exogenous substrate and ADP) is significantly greater in the cold-exposed rats. This increase is in contrast to the unaltered succinate-ADP respiration observed with washed mitochondria.

Thus, the finding in the present study that the P:O ratios are decreased only in liver homogenates from cold-exposed rats and not in washed mitochondria supports the finding of Smith (1960) that such a suppression of P:O ratios occurs only in systems where other cell components are present in addition to the mitochondria. The results also agree with earlier reports that an increased rate of respiration can be observed in liver slices and homogenates from cold-exposed rats (Hannon, 1960; Clark et al., 1954), but that no increase occurs when the measurements are made using mitochondria (Patkin and Masoro, 1960; Chaffee et al., 1961). These data indicate that there is an increased concentration of functional respiratory units in liver tissue of cold-exposed rats. They also indicate that respiration, like oxidative phosphorylation, is influenced by some extra-mitochondrial factors which may be washed out in preparing purified mitochondria.

It is of interest to compare these results with those obtained by Aldridge and Stoner (1963) who found no change in P:O ratios or rates of respiration in either washed or unwashed mitochondria from cold-exposed animals. One explanation would be that the extra-mitochondrial factors, which need to be present in order to demonstrate these changes in cold-exposed rats, may be lost even in the preparation of unwashed mitochondria.

Despite the lack of change in substrate respiration and ATPase activity, it would appear that adaptive changes at the cellular level do occur in the rat during cold exposure which result in an accelerated rate of cellular respiration and a decrease in the efficiency of oxidative phosphorylation. It is further suggested that these results are most easily demonstrated when whole tisue homogenates rather than washed mitochondria are used. These adaptions presumably aid the rat by increasing its capacity to produce heat and thus maintain its normal body temperature in the cold.

Acknowledgments

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AN ANNOTATED CHECKLIST OF VASCULAR PLANTS OF THE SOUTHERN ILLINOIS UNIVERSITY PINE HILLS FIELD STATION AND ENVIRONS

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ABSTRACT. — A descriptive account of the Pine Hills Field Station and environs in Union County, Illinois is presented, followed by an annotated checklist of the vascular plants thus far found in the area. A total of 1003 species is included. This high total is a reflection of the diverse habitats found in the area.

In 1959, Southern Illinois University established a Field Station in an area popularly known as the Pine Hills, in northwestern Union County, Illinois. This area lies in the extreme western section of the Shawnee National Forest. Swamps, unspoiled mixed deciduous forest, cold water springs of even temperature, clear-running rock-bottomed streams, steep-sided and shaded valleys, dry rocky uplands, acid cherty slopes of varied aspect, grassy openings or hill prairies, and limestone provide a wide habitat range.

Early collections from the Pine Hills area were made by Henry Al-

FIGURE 1.—Map showing study area. The Southern Illinois University Field Station is delimited by the dotted line. Prepared by Cartographic Office, Mississippi Valley Investigation, Dan Irwin, 1959. Source: U.S.G.S. Wolf Lake Quadrangle.

len Gleason in the early 1900's. During the past decade and a half, the principal collections of vascular plants in the area were by the late Professor William C. Bailey and by Julius R. Swayne. The present authors and their students, long realizing the unusual floristic composition, interest, and overlapping vegetational patterns of the area, have made repeated trips there for study, and these efforts are incorporated in "A Flora of Southern Illinois". There has never been an exhaustive checklist prepared on the Pine Hills area.

Geographically situated between the Appalachians and the Ozarks, southern Illinois owns a natural relationship to both and thus becomes a giant link in nature's floristic gradient. A general reduction in size of individual plants and their numbers occurs in the spread of species to the west. A climatic gradient condition of moist to dry is the underlying cause. There lie to the west, to the north, or to the south, floral assemblies of different origin and nature.

From LaRue, situated at the east edge of the ancient floodplain of the Mississippi River, may be seen a towering limestone bluff capped with chert and supporting yellow pines *(Pinus echinata)*. Below the bluff is a sizable swamp. Numerous springs issue from the base of the limestone bluffs and one large one flows under the road. Its waters are cold, as indicated by the abundance of water cress in the channel of its flow. The temperature of the water holds uniform through the summer. This spring is noted for its unique animal forms. Here may be found pygmy sunfish *(Elassoma zonatum)* no longer than 1.5 inches. Blind cave fish *(Chlogaster papilliferus)* occasionally are washed from their subterranean caverns. Beavers are active in this area and construct extensive dams to maintain a certain water level. The swamp is a haven for many forms of animal life.

Where Wolf Lake becomes narrower and shallower at its northern limit, Wolf Lake Swamp originates. The northern border of this swamp arbitrarily is set at the road which extends from Illinois Route 3 eastward to the base of the massive limestone bluffs known as the Pine Hills. These bluffs form the eastern limit of the swamp. To the west, a gradual rise in elevation is responsible for the dissipation of the swamp into a low woodland area.

In the constantly inundated area, the standing water varies from one inch or so at times of lowest water to about five feet in depth. Different groupings of plants are recognized with relation to the depth of water in the swamps. In areas which may become covered by five feet of water, buttonbush is most abundant. Trees are numerous, but only a small percentage of them is living. Among the trees present are black willow *(Salix nigra)*, swamp cottonwood, and red maple. Occasional plants of pondweed and naiad are found. Growing as an epiphyte on bases of some of the trees is the water horehound *(Lycopus rubellus)*.

In water that sometimes is two feet deep, large monocotyledonous perennials such as sweet flag, arrow-leaf, arrow-arum, and bur-reed *(Sparganium eurycarpum* and *S. androcladum)* are common. Trees are more abundant where the water is shallower. Pumpkin ash *(Fraxinus tomentosa)*, red maple, swamp cottonwood, water locust *(Gleditsia aquatica)*, and honey locust are rather common. Coarse sedges abound in this shallow water area. Numbered among these are *Carex lupuliformis*, *C. lurida*, *C. hystricina*, *C. lupulina*, and *C. stipata*. Free-floaters present are spongeplant *(Limnobium spongia)*, watermeal, species of duckweed *(Lemna trisulca* and *L. minor)*, and mosquito fern *(Azolla mexicana)*.

A distinct woodland community on low ground, in which the area is inundated for only a portion of each year, exists in the outer regions of the swamp. Tree composition is somewhat different from the swamp proper. Swamp cottonwood, red maple, and honey locust still occur, but in smaller numbers. With these are silver maple, pin oak *(Quercus palustris)*, box elder (*Acer negundo*), and sweet gum *(Liquidambar styracif-*

lua) in appreciable numbers, while occasional plants of slippery elm *(Ulmus rubra)*, basket oak *(Quercus michauxii)*, and white oak *(Quercus alba)* occur. Only gray dogwood *(Cornus obliqua)* and Virginia willow *(Itea virginica)* are found in the shrub layer. The understory is sparsely populated, but a large variety of species occurs. Most abundant are pink St. John's-wort *(Triadenum walteri)*, hydrolea *(Hydrolea affinis)*, water parsnip (*Sium suave*) monkey-flower (*Mimulus alatus*), and bedstraw (*Galium obtusum*). Gerardia (*Gerardia tenuifolia*), butterwood (*Senecio glabellus*), swamp milkweed (*Asclepias perennis*), and enchanter's nightshade (*Circaea latifolia*) are less common. Rare species are skullcap (*Scutellaria nervosa*) and bishop's-weed (*Ptilimnium costatum*). All except butterweed flower during the summer and fall.

Near the base of a limestone bluff in T 11 S, R 3 W, section 18, is an area of deeper water. This is called Otter Pond. The borders are thickly populated with buttonbush and Virginia willow.

North of the road extending from Illinois Route 3 to the Pine Hills is the southern end of the LaRue Swamp. This swamp, also bounded to the east by limestone bluffs, is much more extensive than the Wolf Lake Swamp. It covers an area nearly two-and-three-fourths miles long and from one-eighth to one mile broad. It is fed by refreshing limpid springs which are at the base of the limestone bluffs. Colonies of beavers live in LaRue Swamp. The presence of their dams across the swamp results in the constant back-up of the water. In more quiet areas where the water seldom is in motion, stagnation frequently occurs. The animals of this swamp (termed the Pine Hills Swamp), particularly the fishes, have been discussed by Gunning and Lewis (1955).

As the spring water emerges it has a year around temperature between 56° and 58° F (Gunning and Lewis, 1955). In the rapidly flowing water at the springhead, only water-cress *(Nasturtium officinale)* thrives. In adjacent areas where there is moderate water movement resulting from the rapid currents of the spring's main channel, additional species occur. These, for the most part, are species which also inhabit the borders of streams in southern Illinois. Included here are ditch stone-crop *(Penthorum sedoides)*, water plantain *(Alisma plantago-aquatica* var. *parviflorum)*, pink swamp milkweed *(Asclepias incarnata)*, and mild water pepper, along with manna grass *(Glyceria septentrionalis)* and sedge *(Carex vulpinoidea)*. In a zone from three to fifteen feet wide on either side of the spring's main channel is a unique community of plants. The area inhabited by these plants is inundated by one to six inches of water for most of each year. Unusually occurring species, many of which are found in no other place in the swamp, are in this zone. Among the rarer ones are bulrush *(Scirpus validus)*, two grasses *(Puccinellia pallida* and *Glyceria arkansana)*, and American feather-foil *(Hottonia inflata)*. Cat-tail *(Typha latifolia)* is common at this site.

The constantly inundated regions of LaRue Swamp are similar to those of Wolf Lake Swamp except that more species exist in LaRue Swamp. Trees are common, with pumpkin ash clearly comprising 60 per cent of those present. In moderate numbers are red ash, red maple, swamp cottonwood, southern hackberry (*Celtis laevigata*), and water locust. In the most remote parts of the swamp are a few scattered trees of bald cypress *(Taxodium distichum)* and Drummond's red maple *(Acer drummondii)*.

Shrubs are plentiful in the standing water. Buttonbush again is encountered most frequently, but thickets of water willow *(Decodon verticillatus)* and swamp rose *(Rosa palustris)* become established locally.

Herbaceous members of the standing water community are not frequent, but those that are present usually have vivid flowers. Yellow water crowfoot *(Ranunculus flabellaris)*, water primrose *(Jussiaea decurrens)*, water mustard *(Neobeckia aquatica)*, and American featherfoil are particularly attractive. In more shallow water are coarse monocotyledons. Some of these are *Carex lupulina*, *C. lupuliformis*, *C. retrorsa*, *C. comosa*, *C. stipata*, and *C. crus-corvi*. Growing as epiphytes on the bases of pumpkin ash and southern hackberry are clumps of the cypress-knee sedge *(Carex decomposita)*. A few small unusual herbs such as bladderworts *(Utricularia vulgaris* and *U. gibba)* and red iris *(Iris fulva)* occur. In the stagnated areas, free-floaters abound, among which are mosquito fern, duckweeds, watermeal, and sponge-plant.

The partly inundated periphery of LaRue Swamp contains species which

occur in other open moist habitats in southern Illinois. Spring-flowering species include mousetail *(Myosurus minimus)* and Pennsylvania water cress *(Cardamine pennsylvanica)*. Those which begin to flower in June are water dock, lizard's-tail, water parsnip, and bishop's weed.

The swamp gives way to a woodland community on low ground which is essentially like the low woodland community bordering the Wolf Lake Swamp. Dominant trees are red maple, honey locust, and swamp cottonwood, with silver maple, sweet gum, and pin oak present in considerable numbers. Swamp holly *(Ilex decidua)* is the most frequently encountered shrub. The understory has the same composition as the Wolf Lake Swamp lowland woods except that the pink St. John's-wort and hydrolea are not as common in the former.

The following lists show the association of plants in their ecological situations.

Woody Species of Constantly Inundated Areas:

Acer drummondii
Acer rubrum
Celtis laevigata
Cephalanthus occidentalis
Decodon verticillatus
Fraxinus pennsylvanica
Fraxinus tomentosa
Gleditsia aquatica
Itea virginica
Populus heterophylla
Rosa palustris
Salix nigra
Taxodium distichum

Woody Species of Areas Inundated only a Part of Each Year:

Acer rubrum
Celtis laevigata
Cephalanthus occidentalis
Fraxinus pennsylvanica
Gleditsia triacanthos
Itea virginica
Populus heterophylla
Rosa palustris
Salix nigra

Woody Species of Low Woodlands Which May Never Grow in Water:

Acer negundo
Acer saccharinum
Betula nigra
Celtis laevigata
Cephalanthus occidentalis
Cornus obliqua
Fraxinus pennsylvanica
Gleditsia triacanthos
Ilex decidua
Itea virginica
Liquidambar styraciflua
Quercus alba
Quercus palustris
Quercus michauxii
Ulmus rubra

Herbaceous Species Which May Be Free Floaters:

Azolla mexicana
Cabomba caroliniana
Lemna minor
Lemna perpusilla
Lemna valdiviana
Lemna trisulca
Limnobium spongia
Naias flexilis
Potamogeton diversifolius
Spirodela polyrhiza
Wolffia columbiana
Wolffia papulifera
Wolffiella floridana

Rooted Herbaceous Species Which May Be Found in Constantly Inundated Areas:

Acorus calamus
Alisma plantago-aquatica var. *parviflorum*
Alopecurus aequalis
Asclepias perennis
Bidens polylepis
Brasenia schreberi
Carex comosa
Carex crus-corvi
Carex frankii
Carex lupuliformis
Carex lupulina
Carex lurida
Carex retrorsa
Carex stipata
Ceratophyllum demersum
Echinodorus cordifolius
Galium tinctorium
Glyceria arkansana
Hottonia inflata
Iris fulva
Jussiaea decurrens
Ludwigia palustris
Lycopus rubellus
Nasturtium officinale
Nelumbo lutea
Neobeckia aquatica

Nuphar advena
Nymphaea odorata
Peltandra virginica
Pontederia cordata
Puccinellia pallida
Ranunculus flabellaris
Sagittaria latifolia
Scirpus validus
Sparganium androcladum
Sparganium eurycarpum
Utricularia gibba
Utricularia vulgaris

Herbs in Partly Inundated Areas, No Canopy:

Agrostis palustris
Asclepias perennis
Aster simplex
Aster vimineus
Cardamine pennsylvanica
Carex vulpinoidea
Commelina diffusa
Cyperus erythrorhizos
Cyperus ferruginescens
Cyperus aristatus
Epilobium coloratum
Eragrostis hypnoides
Eupatorium coelestinum
Glyceria striata
Heliotropium indicum
Hibiscus lasiocarpus
Ipomoea lacunosa
Leersia lenticularis
Leesia oryzoides
Lindernia dubia
Lobelia cardinalis
Lycopus americanus
Lycopus rubellus
Mentha spicata
Muhlenbergia frondosa
Muhlenbergia schreberi
Myosurus minimus
Panicum agrostoides
Paspalum fluitans
Paspalum geminum
Pluchea camphorata
Polygonum hydropiper
Polygonum hydropiperoides
Polygonum sagittatum
Ptilimnium costatum
Rumex verticillatus
Saururus cernuus
Scutellaria lateriflora
Sium suave

Herbs of the Low Woodland Community:

Apios americana
Asclepias perennis
Aster simplex
Aster vimineus
Bidens comosa
Bidens discoidea
Bidens vulgata
Cardamine pennsylvanica
Circaea latifolia
Galium obtusum
Gerardia tenuifolia
Glyceria septentrionalis
Hydrolea affinis
Hypericum perforatum
Lycopus americanus
Lycopus rubellus
Lysimachia ciliata
Ptilimnium costatum
Scutellaria lateriflora
Scutellaria nervosa
Senecio glabellus
Sium suave
Stachys tenuifolia
Traiadenum walteri

Continuing along the edge of the swamp, the road winds from low ground where stately beech trees *(Fagus grandifolia)*, tulip trees *(Liriodendron tulipifera)*, and maple *(Acer spp.)* prevail. Large sassafras *(Sassafras albidum)* and cucumber trees *(Magnolia acuminata)* mingle with them.

From the roadside in sandy areas of low ground may be seen tongues and patches of cleft phlox *(Phlox bifida)*, carpets of mist flower *(Phacelia purshii)*, and spatterings of purple delphinium *(Delphinium tricorne)*. Buttercups *(Ranunculus spp.)*, trilliums *(Trillium spp.)*, and bloodroot *(Sanguinaria canadensis)* are numerous. Layers of redbud *(Cercis canadensis)* and dogwood *(Cornus florida)* may be seen at the roadside under the canopy of taller trees.

On higher elevations are found communities of white oak *(Quercus alba)*, black oak *(Q. velutina)*, and red oak *(Q. rubra)* to the crests where dryness induced by greater exposure presents the post oak *(Quercus stellata)* and black-jack oak *(Q. marilandica)* communities. These tree segregates occur and re-occur where suitable habitats are found and there are many interminglings to form still other assemblages.

The greatest occurrence of yellow pine in southern Illinois is in Pine Hills, Union County. The pines are found from mid-slope to near the ridge-tops, becoming progressively more abundant near the top. The soil is a thin layer of rocks, reddish chert, underlain by massive limestone. Yellow pine and Buckley's hickory usually are the leading dominants. Other canopy species

include pignut hickory, white oak, black oak, red oak, black-jack oak, and shagbark hickory.

An abundant shrub layer is dominated by high-bush blueberry *(Vaccinimm vacillans)* and sparkleberry *(V. arboreum)*. Other common shrubs are shining sumac *(Rhus copallina)*, fragrant sumac *(R. aromatica)*, New Jersey tea *(Ceanothus americanus)*, and wild rose *(Rosa setigera)*. Locally on these cherty west-facing slopes may be found scattered bushes of the pinxter flower (*Rhododendron* spp).

The herbaceous layer here is composed predominantly of summer and fall-flowering species. Early spring-blooming species are plantain-leaved everlasting or pussy toes *(Antennaria plantaginifolia)*, and four species of sedge *(Carex artitecta, C. emmonsii, C. physorhyncha*, and *C. umbellata)*. This period is followed closely by blooming of cleft phlox and bird's-foot violet *(Viola pedata)*. From mid-May until October, there is a rapid succession of goat's-rue *(Tephrosia virginiana)*, bedstraw *(Galium circaezans)*, shooting star *(Dodecatheon media)*, milkweed *(Asclepias quadrifolia)*, bee balm *(Monarda bradburiana)*, poverty oat-grass *(Danthonia spicata)*, pencil flower *(Stylosanthes biflora)*, three-seeded mercury *(Acalypha gracilens)*, and several species of sunflower and goldenrod. The latter is interesting, floristically, since two species *(Solidago strigosa* and *S. bootii)* are known only from this station in Illinois.

A few woody species are able to send roots into cracks and crevices of the limestone bluffs. These plants, because of the extreme environmental conditions to which they are subjected, are usually gnarled and stunted. Included in this group are dwarf hackberry *(Celtis pumila)*, red cedar *(Juniperus virginiana)*, and blue ash (*Fraxinus quadrangulata)*. Several vines cling to exposed bluff faces. Some of these are Virginia creeper *(Parthenocissus quinquefolia)*, bur cucumber *(Sicyos angulatus)*, and snailseed *(Cocculus carolina)*.

A few herbaceous species occurring under such rigorous environmental conditions as imposed on a bluff face are cleft phlox, wild onion *(Allium stellatum)*, walking fern *(Camptosorus rhizophyllus)*, black spleenwort *(Asplenium resiliens)*, tiny lip-fern *(Cheilanthes feei)*, purple cliffbreak *(Pellaea atropurpurea)*, and bulblet bladderfern *(Cystopteris bulbifera)*. Less common species of this habitat include shrubby bluet *(Houstonia nigricans)* and *Isanthus brachiatus*.

Along the road near the summit of the Pine Hills occurs Hill Prairie on Government Rock. This hill prairie occurs on exposed upper slopes of southwest and west-facing bluffs. The factors most influential in determining the vegetation of these slopes are the location and topography. Most hill prairies are directly exposed to hot afternoon sun and prevailing southwest summer winds. It is under these extreme dry conditions that the prairie thrives when surrounded by forest vegetation. Since hill prairies often occur on steep slopes, many are not easily accessible and, therefore, little disturbed.

Species composition of the hill prairie seems to be chiefly characteristic of the western plains and the Ozark plateau, although a number of plants have a southern origin. Since the territory is unglaciated, it is supposed that these prairies have a pre-glacial origin. The hill prairies show an array of herbs in their seasonal aspects. Outstanding among these are puccoon *(Lithospermum canescens)* and verbena *(Verbena canadensis)* of the spring aspect. The cone flower *(Echinacea pallida)* and purple *(Petalostemum purpureum)* and white prairie clover *(P. candidum)* are the outstanding herbs of the summer aspect. The autumnal sun is reflected in a burst of brilliant color. Boneset *(Kuhnia eupatorioides)*, goldenrods *(Solidago* spp.), and asters hold forth until frost.

Among the dominant grasses it is little bluestem *(Andropogon scoparius)* which in its greater abundance (nearly 70 per cent of the composition) gives the hill prairie a western look. Next in rank is side-oats grama *(Bouteloua curtipendula)*. It flowers during early summer and becomes more conspicuous with its oat-like spikelets displayed on one side of its flowering rachis at one-and-one-half to two feet high. Only a scattering of the taller grasses occurs on this upland site. Two species, big bluestem *(Andropogon gerardii)* and Indian grass *(Sorghastrum nutans)*, are predominant.

Ashby and Kelting (1963) have presented a detailed account of the vegetation of the Pine Hills Field Station.

The State of Illinois is presently known to have over 2700 species of vascular plants. The southern twelve county area is known to have nearly 1600 species (Mohlenbrock and Voigt, 1959). Jackson County has the greatest list of vascular plants with nearly 1400 species. One of the richest concentrations of species in a single area exists at Giant City State Park where 820 species are known on 1535 acres (Mohlenbrock, 1954).

The area covered by this annotated checklist is in the northwest township of Union County (Preston Township). It includes the area shown in Figure 1.

The annotated checklist which follows accounts for all vascular plants from the Pine Hills Field Station and environs for which herbarium specimens have been taken. A total of 1003 species distributed in 441 genera and 120 families is included. Brief mention concerning habitat and abundance is made for each species. An asterisk (*) preceding the species indicates a plant adventive to the area. The number following the collector's name is the collector's field number for that particular specimen.

Subphylum SPHENOPSIDA Scott

EQUISETACEAE Michx.—Horsetail Family

Equisetum arvense L. Field Horsetail. Moist soil, occasional; *R. Mohlenbrock 13920.*

Equisetum hyemale L. Tall Scouring Rush. Wet ground and in swamps, common; *J. Voigt s.n.*

Subphylum PTEROPSIDA Jeffrey

Class FILICINEAE Brongn.

OPHIOGLOSSACEAE Presl—Adder's-tongue Family

Botrychium obliquum Muhl. Grape Fern. Shaded woods, occasional; *R. Mohlenbrock 12458.*

Botrychium virginianum (L). Sw. Rattlesnake Fern. Moist woods, common; *R. Mohlenbrock 12688.*

Ophioglossum vulgatum L. Adder's-tongue Fern. Low woods, rare; *W. Bailey & J. Swayne 741.*

POLYPODIACEAE R. Br.—Fern Family

Adriantum pedatum L. Maidenhair Fern. Rich woods, common; *R. Mohlenbrock 12745.*

Asplenium pinnatifidum Nutt. Pinnatifid Spleenwort. Bluffs, rare; *R. Hatcher 23115.*

Asplenium platyneuron (L.) Oakes. Ebony spleenwort. Woods, common; *J. Voigt s.n.*

Asplenium resiliens Kunze. Black Spleenwort. Limestone bluffs, occasional; *R. Hatcher 23120.*

Athyrium angustum (Willd.) Presl. Lady Fern. Moist woods, occasional; *R. Mohlenbrock 12611.*

Athyrium pycnocarpon (Spreng.) Tidestorm. Glade Fern. Deep woods, occasional; *R. Mohlenbrock, 3597.*

Athyrium thelypterioides (Michx.) Desv. Silvery Spleenwort. Deep woods, occasional; *R. Mohlenbrock 12886.*

Camptosorus rhizophyllus (L.) Link. Walking Fern. Woods, common; *R. Hatcher 186.*

Cheilanthes feei Moore. Baby Lip Fern. Limestone bluffs, occasional; *R. Hatcher 231.*

Cystopteris bulbifera (L.) Bernh. Bulblet Fern. Limestone ravines, occasional; *R. Mohlenbrock 13120.*

Cystopteris fragilis (L.) Bernh. Fragile Fern. Woods, common; *R. Mohlenbrock 7297.*

Dryopteris hexagonoptera (Michx.) C.Chr. Broad Beech Fern. Rich woods, occasional; *R. Mohlenbrock 12414.*

Dryopteris intermedia (Muhl.) A. Gray. Woods, rare; *K. Stewart s.n.*

Dryopteris marginalis (L.) A. Gray. Marginal Wood Fern. Woods, common. *R. Evers 15449.*

Dryopteris spinulosa (O. F. Muell.) Watt. Spinulose Wood Fern. Woods, rare; *K. Stewart s.n.*

Onoclea sensibilis L. Sensitive Fern. Low woods, occasional; *R. Mohlenbrock 8887.*

Pellaea atropurpurea (L.) Link. Purple Cliff Brake. Limestone cliffs, occasional; *M. Steagall 28.*

Polypodium polypodioides (L.) Watt. Resurrection Fern. Woods, rare; *R. Hatcher 231.*

Polypodium virginianum L. Common Polypody. Rocky woods, occasional; *R. Mohlenbrock 12632.*

Polystichum acrostichoides (Michx.) Schott. Christmas Fern. Woods, common; *R. Mohlenbrock & J. Voigt 9966.*

Pteridium latiusculum (Desv.) Hieron. Eastern Bracken. Open woods, occasional; *R. Mohlenbrock 12711.*

Woodsia obtusa (Spreng.) Torr. Cliff Fern. Dry woods, occasional; *R. Mohlenbrock 12443.*

Salviniaceae Reichenb.—Water Fern Family

Azolla mexicana Presl. Mosquito Fern. Swamps, occasional; *R. Hatcher 23130.*

Class GYMNOSPERMAE Lindley

Pinaceae Lindley—Pine Family

Pinus echinata Mill. Shortleaf Pine. Cherty woods, occasional; *G. Winterringer 1692.*

Taxodiaceae Schimper—Bald Cypress Family

Taxodium distichum (L.) Rich. Bald Cypress. Deep swamps, occasional; *W. Stieglitz 41.*

Cupressaceae Horan.—Cypress Family

Juniperus virginiana L. Red Cedar. Edge of bluffs, fields, common; *R. Evers 15476.*

Class ANGIOSPERMAE (Brongn.) A. Br.

Subclass MONOCOTYLEDONEAE (Juss.) DC.

Typhaceae J. St. Hil.—Cat-tail Family

Typha latifolia L. Common Cat-tail. Wet soil, common; *J. Voigt s.n.*

Sparganiaceae J. G. Agardh—Bur-reed Family

Sparganium americanum Nutt. Swamps, rare; *W. Hardy 16.*

Sparganium androcladum (Engelm.) Morong. Swamps, occasional; *W. Stieglitz 44.*

Sparganium chlorocarpum Rydb. Swamps, rare; *S. Abney & G. Dillard 876.*

Sparganium eurycarpum Engelm. Swamps, occasional; *W. Stieglitz 26.*

Potamogetonaceae Engler—Pondweed Family

Potamogeton diversifolius Raf. Wolf Lake, occasional; *W. Bailey & J. Swayne 1713.*

Alismaceae DC.—Water Plaintain Family

Alisma subcordatum Raf. Wet areas, common; *J. Voigt 1139.*

Echinorodus cordifolius (L.) Griseb. Swamps, occasional; *J. Voigt 681.*

Echinodorus rostratus (Nutt.) Engelm. Swamps, rare; *W. Stieglitz 45.*

Sagittaria latifolia Willd. Around lakes and swamps, common; *W. Bailey & J. Swayne 1789.*

Sagittaria rigida Pursh. Edge of swamps, rare; *J. Voigt s.n.*

Hydrocharitaceae Aschers.—Frog-bit Family

Limnobium spongia (Bosc) Steud. Sponge-plant. Swamps and lakes, occasional; *W. Stieglitz 20.*

GRAMINEAE Juss.—Grass Family

Agrostis alba L. Red-top. Woods, common; *J. Voigt s.n.*

Agrostis hyemalis (Walt.) BSP. Tickle Grass. Woods and fields, common; *R. Mohlenbrock 12856.*

Agrostis palustris Huds. Swamps, occasional; *R. Mohlenbrock 12973.*

Agrostis perennans (Walt.) Tuckerm. Woods, common; *J. Voigt 14936.*

Alopecurus aequalis Sobol. Wet soil, rare; *J. Voigt 1369.*

Alopecurus carolinianus Walt. Common Foxtail. Waste ground, common; *J. Voigt 2614.*

Andropogon gerardii Vitm. Big Blue Stem. Hill prairies, common; *J. Voigt 2619.*

Andropogon scoparius Michx. Little Blue Stem. Hill prairies, common; *J. Voigt 2618.*

Andropogon virginicus L. Broomsedge. Fields, common; *J. Voigt 2622.*

Aristida dichotoma Michx. Fields, common; *J. Voigt 2617.*

Aristida longespica Poir. Fields, common; *R. Mohlenbrock 13921.*

Aristida oligantha Michx. Three-awn. Fields, common; *R. Mohlenbrock 12459.*

Aristida ramosissima Engelm. Fields, occasional; *J. Voigt s.n.*

Arundinaria gigantea (Walt.) Muhl. Giant Cane. Low ground, common; *J. Voigt 759.*

Bouteloua curtipendula (Michx.) Torr. Side-oats Grama. Hill prairies, common; *J. Voigt 16636.*

Brachyelytrum erectum (Schreb.) Beauv. Woods, common; *R. Mohlenbrock 12689.*

Bromus ciliatus L. Woods, occasional; *J. Voigt 2307.*

**Bromus commutatus* Schrad. Waste ground, common; *J. Voigt s.n.*

**Bromus inermis* Leyss. Waste ground, occasional; *J. Voigt s.n.*

**Bromus japonicus* Thunb. Exposed ledges, common; *J. Ozment.*

Bromus purgans L. Woods, occasional; *R. Mohlenbrock 12746.*

**Bromus racemosus* L. Exposed ledges, common; *J. Ozment s. n.*

**Bromus secalinus* L. Waste ground, common; *J. Voigt 2917.*

**Bromus tectorum* L. Waste ground, common; *J. Voigt 1581.*

Cinna arundinacea L. Wood Reed Grass. Low woods, common; *J. Voigt 14077.*

**Dactylis glomerata* L. Waste ground, common; *R. Mohlenbrock 12612.*

Danthonia spicata (L.) Beauv. Poverty Oat Grass. Dry Woods, common; *J. Voigt 2215.*

Diarrhena americana Beauv. Moist woods, rare; *J. Voigt s.n.*

**Digitaria ischaemum* (Schreb.) Muhl. Crab-grass. Waste ground, occasional; *R. Mohlenbrock s.n.*

**Digitaria sanguinalis* (L.) Scop. Crab-grass. Waste ground, common; *J. Voigt 2619.*

Echinochloa crusgalli (L.) Beauv. Barnyard Grass, Waste ground, common; *W. Stieglitz 7.*

Echinochloa pungens (Poir.) Rydb. Moist ground, occasional; *R. Mohlenbrock s.n.*

Echinochloa walteri (Pursh) Heller. Edge of lakes and swamps, occasional; *J. Voigt 14958.*

**Eleusine indica* (L.) Gaertn. Goose-grass. Waste ground, common; *J. Voigt s.n.*

Elymus villasus Muhl, Woods, common; *J. Voigt 763.*

Elymus canadensis L. Woods, common; *J. Voigt 2141*

Elymus virginicus L. Wild Rye. Woods, common; *W. Stieglitz 32.*

Eragrostis capillaris (L.) Nees. Exposed ledges, common; *J. Ozment s.n.*

**Eragrostis cilianensis* (All.) Link. Waste ground, common; *J. Voigt 2512.*

Eragrostis frankii C. A. Mey. Sandy, moist soil, rare; *J. Voigt 2013.*

Eragrostis hypnoides (Lam.) BSP. Pony Grass, Wet soil, common; *W. Stieglitz 11.*

Eragrostis pectinacea (Michx.) Nees. Woods and roadsides, common; *R. Mohlenbrock 3510.*

**Eragrostis poaeoides* (L.) Beauv. Wet ground, occasional; *W. Bailey & J. Swayne 3055.*

Eragrostis spectabilis (Pursh) Steud. Woods, common; *J. Voigt 3012.*

Erianthus alopecuroides (L.) Ell. Plume Grass. Edge of woods, rare; *R. Mohlenbrock 3926.*

**Eriochloa contracta* Hitchc. Waste ground, rare; *J. Voigt 8408.*
**Festuca elatior* L. Waste ground along roads, common; *J. Voigt 660.*
Festuca obtusa Bieler. Woods, occasional; *J. Voigt 1961.*
Festuca octoflora Walt. Eight-Weeks Fescue. Dry areas, common; *J. Voigt s.n.*
Festuca paradoxa Desv. Woods, rare; R. Mohlenbrock & *J. Voigt 9022.*
Glyceria arkansana Fern. Swamps, rare; *R. Hatcher 436.*
Glyceria septentrionalis Hitchc. Wet woods, rare; *W. Bailey & J. Swayne 1489.*
Glyceria striata (Lam.) Hitchc. Low woods, common; *J. Voigt 3420.*
**Hordeum jubatum* L. Barley. Waste ground, occasional; *J. Voigt 685.*
**Hordeum pusillum* Nutt. Small Barley. Waste ground, common; *J. Voigt 2944.*
Hystrix patula Moench. Bottlebrush Grass. Woods, common; *R. Mohlenbrock 10990.*
Koeleria cristata (L.) Pers. Hill prairies, rare; *J. Voigt 3000.*
Leersia lenticularis Michx. Wet ground, occasional; *R. Mohlenbrock 5419.*
Leersia oryzoides (L.) Sw. Cut Grass. Low woods, common; *W. Stieglitz 5.*
Leersia virginica Willd. White Grass. Low woods, common; *J. Voigt 13923.*
Leptochloa fascicularis (Lam.) A. Gray. Along edge of swamp, rare; *J. Voigt s.n.*
Leptochloa filiformis (Lam.) Beauv. Along lakes, occasional; *R. Mohlenbrock 12887.*
**Lolium multiflorum* Lam. Waste ground, common; *R. Mohlenbrock 13121.*
**Lolium perenne* L. Perennial Rye Grass. Waste ground, common; *W. Bailey & J. Swayne 2495.*
Melica mutica Walt. Woods, rare; *J. Voigt 692.*
Melica nitens (Scribn.) Nutt. Woods, occasional; *J. Voigt 1370.*
Muhlenbergia capillaris (Lam.) Trin. Woods, rare; *R. Evers 23414.*
Muhlenbergia cuspidata (Torr.) Rydb. Exposed ledges, occasional; *J. Ozment.*
Muhlenbergia frondosa (Poir.) Fern. Woods, rare; *J. Voigt 14078.*
Muhlenbergia mexicana (L.) Trin. Woods, rare; *J. Voigt 3616.*
Muhlenbergia racemosa (Michx.) BSP. Wet ground, occasional; *J. Voigt 2717.*
Muhlenbergia schreberi J. F. Gmel. Nimble Will. Woods, common; *W. Bailey & J. Swayne 3041.*
Muhlenbergia sobolifera (Muhl.) Trin. Woods, common; *R. Mohlenbrock & J. Voigt 9969.*
Muhlenbergia sylvatica Torr. Woods, occasional; *R. Mohlenbrock 13886.*
Muhlenbergia tenuiflora (Willd.) BSP. Rocky woods, occasional; *R. Mohlenbrock 12413.*
Panicum agrostoides Spreng. Wet ground, common; *R. Mohlenbrock 12631.*
Panicum anceps Michx. Moist soil, common; *J. Voigt 14898.*
Panicum boscii Poir. Woods, common; *R. Mohlenbrock 12710.*
Panicum capillare L. Witch Grass. Woods and roadsides, common; *R. Mohlenbrock 12424.*
Panicum clandestinum L. Deer-tongue Grass. Woods, occasional; *R. Mohlenbrock s.n.*
Panicum commutatum Schult. Woods, occasional; *J. Voigt 2848.*
Panicum depauperatum Muhl. Woods and fields, common; *J. Voigt 2170.*
Panicum dichotomiflorum Michx. Woods, common; *W. Stieglitz 4.*
Panicum dichotomum L. Dry woods, occasional; *R. Mohlenbrock s.n.*
Panicum flexile (Gattinger) Scribn. Woods, common; *J. Voigt 14319.*
Panicum huachucae Ashe. Open areas, common; *R. Mohlenbrock 12972.*
Panicum lanuginosum Ell. Woods, rare; *J. Voigt 687.*
Panicum latifolium L. Woods, occasional; *R. Mohlenbrock 13922.*
Panicum leibergii (Vasey) Scribn. Cherty slopes, rare; *R. Mohlenbrock 12460.*
Panicum lineariifolium Scribn. Woods, occasional; *K. Stewart 97.*
Panicum microcarpon Muhl. Woods, common; *J. Voigt 791.*
Panicum philadelphicum Bernh. Woods, rare; *R. Mohlenbrock 12690.*
Panicum polyanthes Schult. Woods, occasional; *R. Mohlenbrock 12747.*
Panicum scribnerianum Nash. Woods, occasional; *J. Voigt 12613.*
Panicum tennesseense Ashe. Moist ground, common; *R. Mohlenbrock 9261.*
Panicum virgatum L. Moist ground, common; *J. Voigt s.n.*
Panicum xalapense HBK. Woods and fields, common; *J. Voigt 2888.*
Paspalum circulare Nash. Wet ground, occasional; *W. Stieglitz 9.*
Paspalum fluitans (Ell.) Kunth. Around lake, rare; *R. Mohlenbrock 14089.*

Paspalum geminum Nash. Edge of swamps, occasional; *R. Mohlenbrock 3863.*
Paspalum pubescens Muhl. Woods, occasional; *R. Mohlenbrock 2655.*
Paspalum stramineum Nash. Woods and fields, occasional; *J. Voigt 1812.*
**Phleum pratense* L. Timothy. Waste ground, occasional; *R. Mohlenbrock 12613.*
**Poa annua* L. Annual Blue Grass. Waste ground, common; *R. Mohlenbrock 12888.*
Poa chapmaniana Scribn. Dry woods, rare; *R. Mohlenbrock 13122.*
**Poa compressa* L. Canadian Blue Grass. Waste ground, common; *J. Voigt 809.*
Poa palustris L. Fowl Blue Grass. Moist soil, rare; *W. C. Ashby s.n.*
**Poa pratensis* L. Kentucky Blue Grass. Waste ground and woods, common; *J. Voigt 810.*
Poa sylvestris A. Gray. Woods, occasional; *R. Mohlenbrock 13885.*
Puccinellia pallida (Torr.) Clausen. Swamps, rare; *W. Bailey & J. Swayne 2485.*
**Secale cereale* L. Rye, Along levee, occasional; *R. Mohlenbrock s.n.*
**Setaria faberi* Herrm. Giant Foxtail. Waste ground, common; *R. Mohlenbrock 12412.*
**Setaria lutescens* (Weigel) F. T. Hubb. Yellow Foxtail. Waste ground, common; *R. Mohlenbrock 12630.*
Setaria viridis (L.) Beauv. Green Foxtail. Waste ground, common; *J. Voigt 762.*
Sorghastrum nutans (L.) Nash. Indian Grass. Hill prairies, occasional; *J. Voigt 14806.*
Sorghum halepense (L.) Pers. Johnson Grass. Waste ground, common; *J. Voigt 3209.*
Spenopholis intermedia Rydb. Woods, rare; *J. Voigt 707.*
Sphenopholis nitida (Bieler) Scribn. Cherty slopes, rare; *R. Mohlenbrock 12709.*
Sphenopholis obtusata (Michx.) Scribn. Woods, occasional; *J. Voigt 1164.*
Triodia flava (L.) Smyth. Red-top. Fields and roadsides, common; *R. Mohlenbrock 14076.*
Tripsacum dactyloides L. Wild Corn. Moist soil, rare; *R. Mohlenbrock 12441.*
**Triticum aestivum* L. Wheat. Waste ground, occasional; *J. Voigt 229.*
Uniola latifolia Michx. Sea Oats. Woods, common; *W. Stieglitz 56.*
**Zea mays* L. Corn. Waste ground, occasional; *J. Voigt s.n.*

Cyperaceae J. St. Chil.—Sedge Family

Carex albolutescens Schwein. Woods, rare; *R. Mohlenbrock 12854.*
Carex albursina Sheldon. Moist woods, occasional; *R. Mohlenbrock 12971.*
Carex artitecta Mack. Dry woods, common; *R. Mohlenbrock 13923.*
Carex blanda Dewey. Moist woods, common; *R. Mohlenbrock 12461.*
Carex brevior (Dewey) Mack. Open areas, occasional; *R. Mohlenbrock 12691.*
Carex bushii Mack. Wooded slopes, occasional; *R. Mohlenbrock 12748.*
Carex cephalophora Muhl. Woods and fields, common; *R. Mohlenbrock 12768.*
Carex comosa Boott. Wet ground or in water, common; *K. Stewart 115.*
Carex crinita Lam. Swamps, rare; *J. Voigt 2279.*
Carex cruscorvi Shuttlw. Low woods, occasional; *W. Bailey & J. Swayne 2320.*
Carex decomposita Muhl. On decayed vegetation in swamps; *W. Bailey & J. Swayne 1499.*
Carex emmonsii Dewey. Cherty slopes, rare; *R. Mohlenbrock & R. MacMahon 10142.*
Carex frankii Kunth. Wet ground, common; *W. Bailey & J. Swayne 2782.*
Carex glaucodea Tuckerm. Woods, common; *R. Mohlenbrock 12614.*
Carex gracilescens Steud. Woods, occasional; *R. Mohlenbrock 12889.*
Carex granularis Muhl. Wet soil, common; *R. Mohlenbrock 13123.*
Carex grayii Carey. Low woods, occasional; *R. Mohlenbrock 13884.*
Carex grisea Wahl. Woods, occasional; *R. Mohlenbrock 12411.*
Carex hirsutella Mack. Dry wooded slopes, occasional; *R. Mohlenbrock 12629.*
Carex hyalinolepis Steud. Low woods, common; *K. Stewart & R. Hatcher 109.*
Carex jamesii Schw. Rich woods, occasional; *J. Voigt 8006.*
Carex laevivaginata (Kukenth.) Mack. Wet ground, rare; *J. Voigt 1384.*
Carex lanuginosa Michx. Swamps, occasional; *R. Mohlenbrock s.n.*
Carex lupuliformis Sartw. In swamps, occasional; *R. Mohlenbrock 17417.*
Carex lupulina Muhl. Low ground, common; *W. Stieglitz 33.*
Carex lurida Wahl. Wet situations, common; *J. Voigt 1371.*
Carex muhlenbergii Schk. Mostly dry woods, occasional; *R. Mohlenbrock s.n.*

Carex muskingumensis Schw. Low wet woods, occasional; *J. Voigt 12708.*
Carex oligocarpa Schk. Calcareous woods, rare; *R. Mohlenbrock 16617.*
Carex physorhyncha Liebmann. Cherty slopes, rare; *Mohlenbrock 9927.*
Carex retroflexa Muhl. Woods, common; *R. Mohlenbrock 12440.*
Carex retrorsa Schw. Swamps, rare; *J. Voigt s.n.*
Carex rosea Schk. Moist woods, common; *R. Mohlenbrock 12853.*
Carex scoparia Schk. Woods and along roads, occasional; *R. Mohlenbrock 12970.*
Carex shortiana Dewey. Wet ground, occasional; *J. Voigt 8206.*
Carex squarrosa L. Wet soil, common; *J. Voigt 17369.*
Carex stipata Muhl. Low ground, occasional; *R. Mohlenbrock 15467.*
Carex tribuloides Wahl. Open areas, occasional; *R. Mohlenbrock 13924.*
Carex typhina Michx. Wet areas, common; *R. Mohlenbrock 13883.*
Carex umbellata Schk. Dry rocky woods, occasional; *R. Mohlenbrock 12410.*
Carex vulpinoidea Michx. Wet soil, common; *R. Mohlenbrock 12692.*
Cyperus acuminatus Torr. & Hook. Edge of swamp, occasional; *R. Mohlenbrock 13906.*
Cyperus aristatus Rottb. "Scatters", *W. Bailey & J. Swayne 2984.*
Cyperus engelmanii Steud. Between Larue Swamp and gravel road, low ground, rare; *R. Mohlenbrock 12506.*
Cyperus erythrorhizos Muhl. Low ground in fields and near swamps, occasional; *W. Stieglitz 42.*
Cyperus esculentus L. Edges of fields, common; *R. Mohlenbrock 13907.*
Cyperus ferruginescens Boeck. Edge of LaRue Swamp; around Wolf Lake, common; *W. Hardy 26.*
Cyperus ovularis (Michx.) Torr. In abondoned field, occasional; *R. Mohlenbrock 13908.*
Cyperus strigosus L. Moist soil, common; *W. O. Stieglitz 46.*
Eleocharis acicularis (L.) Roem & Schultes. Edge of lakes and swamps, common; *R. Mohlenbrock 12555.*
Eleocharis obtusa (Willd.) Schultes var. *obtusa*. Wet ground, common; *R. Hatcher s.n.*
Eleocharis obtusa (Willd.) Schultes var. *detonsa* (A. Gray) Drapalik & Mohlenbrock. Wet ground, rare; *R. Mohlenbrock 12587.*
Fimbristylis autumnalis (L.) Roem & Schultes. Edge of Wolf Lake, rare; *R. Mohlenbrock 12562.*
Scirpus atrovirens Willd. Near swamps, common; *R. Mohlenbrock s.n.*
Scirpus cyperinus (L.) Kunth. In shallow water or near swamps, occasional; *R. Mohlenbrock 12571.*
Scirpus lineatus Michx. Moist soil, occasional; *W. Hardy 3.*
Scirpus validus Vahl. In water, occasional; *W. Stieglitz 24.*

Araceae Necker.—Arum Family

Acorus calamus L. Sweetflag. Wolf Lake; edge of Wolf Lake Swamp, occasional; *R. Mohlenbrock 13002.*
Arisaema dracontium (L.) Schott. Green Dragon. Moist woods, common; *R. Mohlenbrock 12872.*
Arisaema triphyllum (L.) Schott. Jack-in-the-Pulpit. Woods, common; *R. Mohlenbrock 12871.*
Peltandra virginica (L.) Kunth. Wolf Lake, rare; *J. Swayne 1141.*

Lemnaceae Dumort.—Duckweed Family

Lemna minor L. Duckweed. Floating in swamps, common; *R. Mohlenbrock 12570.*
Lemna perpusilla Torr. Duckweed. Floating in swamps, rare; *R. Mohlenbrock 13003.*
Lemna trisulca L. Duckweed. Floating in swamps, occasional; *W. Stieglitz 15.*
Lemna valdiviana Phil. Wolf Lake, rare, November 4, 1950, *J. Swayne s.n.*
Spirodela polyrhiza (L.) Schleid. Floating in swamps and lakes, common; *R. Mohlenbrock 13004.*
Wolffia columbiana Karst. Larue Swamp, common; *R. Mohlenbrock 12507.*
Wolffia papulifera C. H. Thompson. Wolf Lake, rare; *J. Swayne 1890.*
Wolffiella floridana (J. D. Sm.) C. H. Thompson. Lakes and swamps, occasional; *J. Swayne 1163.*

COMMELINACEAE Reichenb.—Spiderwort Family

Commelina communis L. Dayflower. Wet ground, common; *R. Mohlenbrock 12561.*

Commelina diffusa Burm. f. Wet ground, common; *R. Mohlenbrock 13905.*

Commelina virginica L. Wet ground in woods, occasional; *R. Mohlenbrock 12508.*

Tradescantia ohiensis Raf. Along road, occasional; *R. Mohlenbrock 13001.*

Tradescantia subaspera Ker-Gawler. Moist woods, common; *R. Sands & D. Drapalik 436.*

Tradescantia virginiana L. Moist ground, common; *R. Mohlenbrock 12586.*

PONTEDERIACEAE Dumort.—Pickerelweed Family

Heteranthera reniformis Ruiz & Pavon. Mud Plantain. Shallow water, very rare.

Pontederia cordata L. Pickerelweed. Wolf Lake, rare; *J. Swayne 1143.*

JUNCACEAE (Vent.) Dumort.—Rush Family

Juncus acuminatus Michx. Wet ground, common; *R. Mohlenbrock 12509.*

Juncus canadensis J. Gay. Wet ground, occasional; *R. Mohlenbrock 12588.*

Juncus dudleyi Wieg. Fields, occasional; *R. Mohlenbrock 12870.*

Juncus effusus L. Shallow water and edges of swamps, common; *W. Stieglitz 55.*

Juncus interior Wieg. Along road, rare; *R. Mohlenbrock 12663.*

Juncus tenuis Willd. Fields and roadsides, common; *R. Hatcher s.n.*

Luzula bulbosa (Wood) Rydb. Wood Rush. Woods, occasional; *R. Mohlenbrock 12592.*

Luzula echinata (Small) Hermann. Dry woods, occasional; *R. Mohlenbrock 12428.*

Luzula multiflora (Retz.) Lejeune. Woods, common; *R. Mohlenbrock 12664.*

LILIACEAE Adans.—Lily Family

Allium canadense L. Wild Garlic. Roadsides and fields, common; *R. Mohlenbrock 12660.*

Allium cepa L. Onion. Escaped along roadside, found once.

Allium stellatum Ker. Hill prairies, limestone bluffs, occasional; *R. Hatcher 706.*

**Allium vineale* L. Field Garlic. Waste ground, common; *J. Voigt 871.*

**Asparagus officeinalis* L. Asparagus. Waste ground, occasional; *J. Voigt 946.*

Camassia scilloides (Raf.) Cory. Wild Hyacinth. Limestone bluffs, occasional; *W. Bailey & J. Swayne 362.*

Erythronium albidum Nutt. White Dog's-tooth Violet. Moist woods, common; *R. Mohlenbrock 12589.*

Erythronium americanum Ker. Yellow Dog's-tooth Violet, Woods, occasional; *R. E. Sands 18.*

**Hemerocallis fulva* L. Day Lily. Along roads, occasional; *J. Voigt 1009.*

Lilium michiganense Farwell. Turk's-cap Lily. Woods, occasional; *R. Mohlenbrock 12591.*

Norhoscordum bivalve (L.) Britt. Dry woods, occasional; *R. Mohlenbrock 957.*

**Ornithogalum umbellatum* L. Star-of-Bethlehem. Along roads, occasional; *R. Mohlenbrock 12563.*

Polygonatum canaliculatum (Muhl.) Pursh. Solomon's Seal. Woods, common; *R. Mohlenbrock s.n.*

Smilacina racemosa (L.) Desf. False Solomon's Seal. Woods, common; *R. Mohlenbrock 12556.*

Smilax bona-nox L. Fringed Greenbrier. Exposed limestone bluffs, occasional; *R. Mohlenbrock 13904.*

Smilax glauca Walt. Sawbrier. Woods, common; *W. Bailey & J. Swayne 2305.*

Smilax hispida Muhl. Common Greenbrier. Woods, occasional; *R. Mohlenbrock 12590.*

Smilax lasioneura Hook. Woods, common; *J. Voigt 1007.*

Smilax pulverulenta Michx. Woods, occasional; *R. Mohlenbrock 12560.*

Smilax rotundifolia L. Woods, occasional; *R. Mohlenbrock 12572.*

Trillium gleasonii Fern. Mesic slopes and ledges, occasional; *J. Ozment.*

Trillium recurvatum Beck. Purple Trillium. Woods, common; *J. Voigt 1424.*

Trillum sessile L. Sessile Trilium. Moist woods, rare; *R. Mohlenbrock 12661.*

Trillium viride Beck. Green Trillium. Woods, rare; *H. Ahles & G. Winterringer 7061.*

Uvularia grandiflora Sm. Bellwort. Moist woods, occasional; *J. Voigt 529.*

Uvularia sessilifolia L. Rich woods, rare; *R. Mohlenbrock s.n.*

DIOSCOREACEAE Lindl.—Yam Family

Dioscorea quaternata (Walt.) J. F. Gmel. Woods, occasional; *R. Mohlenbrock 12429.*

Dioscorea villosa L. Woods, common; *R. Mohlenbrock 13000.*

AMARYLLIDACEAE Lindl.—Amaryllis Family

Agave virginica L. Dry bluff tops, occasional; *J. Ozment.*

Hypoxis hirsuta (L.) Corville. Woods, occasional; *R. Mohlenbrock 12593.*

**Narcissus pseudo-narcissus* L. Daffodil. Roadsides, occasional; *R. Mohlenbrock 12869.*

IRIDACEAE Lindley—Iris Family

Iris cristata Ait. Wooded slope near Wolf Lake, May 15, 1932; *H. Pepoon & Barrett 3578.*

Iris fulva Ker. Red Iris. Swamps. occasional; *J. Voigt 1378.*

Iris shrevei Small. Blue Iris. Wet ground, common; *R. Mohlenbrock 12557.*

Sisyrinchinm albidum Raf. Fields, common; *R. Mohlenbrock 12558.*

Sisyrinchium angustifolium Mill. Wet ground, common; *R. Mohlenbrock 12999.*

ORCHIDACEAE Lindl.—Orchard Family

Corallorhiza wisteriana Conrad. Dry woods, rare; *R. Mohlenbrock s.n.*

Cypripedium parviflorum Salisb. Yellow Ladie's-slipper. Rich woods, rare; *W. Crews s.n.*

Spiranthes ovalis Lindl. Woods, rare; *R. Mohlenbrock 8982.*

Subclass 2. DICOTYLEDONEAE (Juss.) DC.

SAURURACEAE Lindl.—Lizard-tail Family

Saururus cernuus L. Lizard-tail. Wet ground, common; *R. Mohlenbrock 8873.*

SALICACEAE Lindl.—Willow Family

Populus deltoides Marsh. Cottonwood. Low ground, common; *R. Mohlenbrock 12430.*

Populus heterophylla L. Swamp Cottonwood. Edge of swamps, occasional; *R. Mohlenbrock 12431.*

Salix interior Rowlee. Sandbar Willow. Wolf Lake, occasional; *R. Mohlenbrock 12594.*

Salix nigra Marsh. Black Willow. Low ground, common; *R. Mohlenbrock 12998.*

JUGLANDACEAE Horan.—Walnut Family

Carya aquatica (Michx.) Nutt. Swamp, rare; *R. Mohlenbrock s.n.*

Carya cordiformis (Wangenh.) K. Koch. Woods, common; *R. Mohlenbrock 12573.*

Carya glabra (Mill.) Sweet. Usually dry woods, common; *R. Mohlenbrock 12564.*

Carya illinoensis (Wangenh.) K. Koch. Low ground, occasional; *R. Mohlenbrock 12783.*

Carya laciniosa (Michx.) Loud. Low ground, occasional; *R. Mohlenbrock 12565.*

Carya ovalis (Wangenh.) Sarg. Small-fruited Hickory. Woods, occasional: *R. Mohlenbrock 13903.*

Carya ovata (Mill.) K. Koch. Shagbark Hickory. Woods, common; *R. Mohlenbrock 12559.*

Carya texana Bucki. Black Hickory. Exposed bluffs, occasional; *R. Mohlenbrock 12662.*

Carya tomentosa (Poir) Nutt. Mockernut Hickory. Woods, common; *R. Mohlenbrock 278.*

Juglans cinerea L. Butternut. Woods, occasional; *R. Mohlenbrock 12559.*

Juglans nigra L. Woods, common; *R. Mohlenbrock 13005.*

BETULACEAE Agardh—Birch Family

Betula nigra L. River Birch. Low ground, occasional; *R. Mohlenbrock 12432.*

Carpinus caroliniana Walt. Blue Beech. Woods, common; *R. Mohlenbrock 12566.*

Corylus americana Walt. Hazelnut. Thickets, common; *J. Voigt 462.*

Ostrya virginiana (Mill.) K. Koch. Hop Hornbeam. Woods, common; *R. Mohlenbrock 12569.*

FAGACEAE A. Br.—Beech Family

Fagus grandifolia Ehrh. Beech. Moist woods, common; *R. Mohlenbrock 12595.*

Quercus alba L. White Oak, Woods, common; *R. Mohlenbrock 12997.*

Quercus bicolor Willid. Swamp White Oak. Low ground, occasional; *R. Mohlenbrock 12567.*

Quercus coccinea Muench. Scarlet Oak. Woods on cherty slopes, occasional; *R. Mohlenbrock 12574.*

Quercus falcata Michx. Spanish Oak. Woods, occasional; *R. Mohlenbrock 12585.*

Quercus imbricaria Michx. Shingle Oak. Usually low ground, common; *R. Mohlenbrock 12658.*

Quercus lyrata Walt. Overcup Oak. Low ground, rare; *R. Mohlenbrock 12996.*

Quercus macrocarpa Michx. Bur Oak. Lowland woods, occasional; *R. Mohlenbrock 12568.*

Quercus marilandica Muench. Black Jack Oak. Dry upland woods, common; *J. Voigt 982.*

Quercus michauxii Nutt. Basket Oak. Edge of swamps, occasional; *R. Mohlenbrock 12575.*

Quercus muhlenbergii Engelm. Yellow Chestnut Oak. Woods, common; *R. Mohlenbrock 12584.*

Quercus palustris Muench. Pin Oak. Low ground, common; *R. Mohlenbrock 12533.*

Quercus rubra L. Red Oak. Woods, common; *R. Mohlenbrock 12576.*

Quercus shumardii Buckl. Shumard Oak. Woods, occasional.

Quercus stellata Wang. Post Oak. Upland woods, common; *J. Voigt 772.*

Quercus velutina Lam. Black Oak. Woods, common; *J. Voigt 1021.*

ULMACEAE Mirbel—Elm Family

Celtis laevigata Willd. Sugarberry. Edge of swamps and lakes, common; *R. Mohlenbrock 12995.*

Celtis occidentalis L. Hackberry. Woods, occasional; *R. Mohlenbrock 12583.*

Celtis pumila Pursh. Dwarf Hackberry. Dry exposed bluffs, rare; *R. Mohlenbrock 12724.*

Ulmus alata Michx. Winged Elm. Dry upland woods, common; *J. Voigt 427.*

Ulmus americana L. American Elm. Woods, common; *J. Voigt 1020.*

Ulmus rubra Muhl. Slippery Elm. Woods, common; *J. Voigt 980.*

MORACEAE Lindl.—Mulberry Family

Morus rubra L. Red Mulberry. Woods, common; *R. Mohlenbrock 12994.*

URTICACEAE Reichenb.—Nettle Family

Boehmeria cylindrica (L.) Sw. False Nettle. Low woods, common; *J. Voigt s.n.*

Laportea canadensis (L.) Gaudich. Wood Nettle. Woods, common; *R. Mohlenbrock 12657.*

Parietaria pennsylvanica Muhl. Pellitory. Woods, common; *R. Mohlenbrock & J. Voigt s.n.*

Pilea opaca (Lunell) Rydb. Moist sink, base of cherty slope, rare; *R. Mohlenbrock 9223.*

Pilea pumila (L.) A. Gray. Clearweed. Wet ground, common; *W. Stieglitz 29.*

LORANTHACEAE D. Don—Mistletoe Family

Phoradendron flavescens (Pursh) Nutt. Mistletoe. In trees, rare; *R. Mohlenbrock s.n.*

ARISTOLOCHIACEAE Juss.—Birthwort Family

Aristolochia serpentaria L. Virginia Snakeroot. Rich woods, occasional; *R. Mohlenbrock 12577.*

Asarum reflexum Bickn. Wild Ginger. Rich woods, common; *J. Voigt 977.*

POLYGONACEAE Horan.—Buckwheat Family

**Polygonum aviculare* L. Common Knotweed. Waste ground, common; *R. Mohlenbrock 12578.*

Polygonum coccineum Muhl. Edge of swamps, occasional; *R. Sands & D. Drapalik 423.*

Polygonum convolvulus L. Black Bindweed. Fields and woods, occasional; *J. Voigt 1121.*

Polygonum cristatum Engelm. & Gray. Talus slopes, occasional; *J. Ozment.*

Polygonum erectum L. Waste ground, rare; *W. Bailey & J. Swayne 3051.*

Polygonum fluitans A. Eaton. Swamps, rare; *W. Stieglitz 35.*

Polygonum hydropiper L. Water-pepper. Wet ground, occasional; *W. Bailey & J. Swayne 3035.*

Polygonum hydropiperoides Michx. Mild Water-pepper. Wet ground or in shallow water, common; *W. Bailey & J. Swayne 3034.*

Polygonum lapathifolium L. Moist soil, common; *G. Fuller 248.*

Polygonum longistylum Small. Talus slope, rare; *J. Ozment.*

Polygonum opelousanum Riddell. Swampy woods, rare; *W. Stieglitz 27.*

Polygonum pennsylvanicum L. Smartweed. Moist soil, common; *J. Voigt 1072.*

Polygonum persicaria L. Lady's Thumb. Waste ground, common; *R. Mohlenbrock 12579.*

Polygonum punctatum Ell. Water Smartweed. Wet ground, common; *R. Mohlenbrock 12993.*

Polygonum ramosissimum Michx. Bushy Knotweed. Edge of pond, rare; *S. Abney & G. Dillard 192.*

Polygonum sagittatum L. Edge of swamp, occasional; *W. Bailey & J. Swayne 2488.*

Polygonum scandens L. False Buckwheat. Woods, occasional; *J. Voigt 1513.*

Polygonum setaceum Baldw. Edge of swamps, occasional; *W. Bailey & J. Swayne 2773.*

Polygonum virginianum L. Virginia Knotweed. Woods, common; *R. Mohlenbrock 12580.*

Rumex acetosella L. Field Sorrel. Sour Dock. Fields, common; *R. Mohlenbrock 919.*

Rumex altissimus Wood. Pale Dock. Moist soil, common; *R. Mohlenbrock 12992.*

**Rumex crispus* L. Curly Dock. Waste ground, common; *J. Voigt 1133.*

Rumex verticillatus L. Swamp Dock. Wet ground, common; *W. Stieglitz 10.*

Chenopodiaceae Dumort.—Goosefoot Family

**Chenopodium* album L. Lamb's Quarter. Waste ground, common; *R. Mohlenbrock 13902.*

**Chenopodium ambrosioides* L. Mexican Tea. Waste ground, occasional; *J. Voigt 922.*

Chenopodium boscianum Moq. Woods, common; *R. Mohlenbrock 4745.*

Chenopodium hybridum L. Talus slope, occasional; *J. Ozment.*

Chenopodium standleyanum Aellen. Mesic slopes and ledges, occasional; *J. Ozment.*

Amaranthaceae J. St. Hil.—Amaranth Family

Acnida altissima (Riddell) Riddell. Tall Water-hemp. Wet ground, occasional; *W. Bailey & J. Swayne 3228.*

Acnida subnuda (S. Wats.) Standl. Along Hutchins Creek, rare; *R. Mohlenbrock 12656.*

Acnida tamariscina (Nutt.) Wood. Moist soil, occasional; *R. Sands 208.*

Amaranthus albus L. Tumbleweed. Waste ground, occasional; *J. Voigt s.n.*

**Amaranthus graecizans* L. Waste ground, occasional; *J. Voigt s.n.*

Amaranthus hybridus L. Green Amaranth. Waste ground, common; *R. Sands 250.*

Amaranthus retroflexus L. Rough Pigweed. Waste ground, common; *R. Sands s.n.*

**Amaranthus spinosus* L. Spiny Pigweed. Waste ground, common; *R. Sands s.n.*

**Froelichia gracilis* (Hook.) Moq. Waste ground, rare; *R. Sands 245.*

Phytolaccaceae Lindl.—Pokeweed Family

Phytolacca americana L. Pokeweed. Woods and waste places, common; *J. Voigt 884.*

Aizoaceae A. Br.—Carpetweed Family

**Mollugo verticillata* L. Carpetweed. Waste ground, common; *J. Voigt 909.*

ILLECEBRACEAE Lindl.

Paronychia fastigiata (Raf.) Fern. Dry ledges, rare; *J. Ozment.*

PORTULACACEAE Reichenb.—Purslane Family

Claytonia virginica L. Spring Beuty. Woods, common; *R. Mohlenbrock 12991.*

**Portulaca oleracea* L. Purslane. Waste ground, common; *R. Mohlenbrock 13901.*

CARYOPHYLLACEAE Reichenb.—Pink Family

**Agrostemma githago* L. Corn Cockle. Fields, common; *J. Voigt 1222.*

**Cerastium brachypodum* (Engelm.) B. L. Robins. Waste ground, occasional; *W. Bailey & J. Swayne 2087.*

Cerastium nutans Raf. Nodding Mouse-ear Chickweed. Moist ground, common; *R. Mohlenbrock 12581.*

**Cerastium viscosum* L. Waste ground, common; *J. Voigt 1221.*

**Cerastium vulgatum* L. Common Mouse-ear Chickweed. Waste ground, common; *R. Mohlenbrock 12655.*

Dianthus armeria L. Deptford Pink. Waste ground, occasional; *J. Voigt 1137.*

Silene antirrhina L. Sleepy Catchfly. Fields, common; *R. Mohlenbrock 12723.*

Silene stellata (L.) Ait. f. Starry Champion. Woods, common; *R. Mohlenbrock 12990.*

**Stellaria media* (L.) Vill. Common Chickweed. Waste ground, common; *J. Voigt 1301.*

MAGNOLIACEAE J. St. Hil.—Magnolia Family

Liriodendron tulipifera L. Tulip Tree. Woods, common; *R. Mohlenbrock 12433.*

Magnolia acuminata L. Cucumber Tree. Moist woods, occasional; *R. Evers 15497.*

ANNONACEAE R. Br.—Custard-apple Family

Asimina triloba (L.) Dunal. Pawpaw. Woods, common; *J. Voigt 1043.*

RANUNCULACEAE Juss.—Buttercup Family

Actaea alba (L.) Mill. Doll's Eyes. Moist woods, occasional; *J. Voigt 1280.*

Anemone virginiana L. Tall Anemone. Woods, common; *R. Mohlenbrock 12654.*

Anemonella thalictroides (L.) Spach. Woods, common; *R. Mohlenbrock 12596.*

Aquilegia canadensis L. Wild Columbine. Woods and limestone crevices, common; *R. Mohlenbrock 12665.*

Clematis virginiana L. Virgin's Bower. Moist ground, occasional; *G. Fuller 230.*

Delphinium tricorne Michx. Dwarf Larkspur. Rich woods, common; *J. Voigt 1425.* The white-flowering form occurs occasionally.

Isopyrum biternatum (Raf.) Torr. & Gray. False Rue Anemone. Moist woods, common; *R. Mohlenbrock 12989.*

Myosurus minimus L. Mousetail. Waste ground, common; *R. Mohlenbrock 12582.*

Ranunculus abortivus L. Small-flowered Buttercup. Moist soil, common; *R. Mohlenbrock 12597.*

Ranunculus fascicularis Muhl. Tufted Buttercup. Woods, common; *R. Mohlenbrock s.n.*

Ranunculus flabellaris Raf. Swamps and lakes, occasional; *R. Sands 522.*

Ranunculus hispidus Michx. Bristly Buttercup. Woods, common; *R. Mohlenbrock 1876.*

Ranunculus laxicaulis (Torr. & Gray) Darby. Edge of swamps and lakes, occasional; *R. Mohlenbrock 12653.*

Ranunculus micranthus Nutt. Woods, occasional; *R. Mohlenbrock 12598.*

Ranunculus pusillus Poir. Wet ground, rare; *R. Mohlenbrock 12868.*

Ranunculus recurvatus Poir. Moist woods, occasional; *R. Mohlenbrock 12988.*

**Ranunculus sardous* Crantz. Low fields, common; *J. Voigt 1330.*

Ranunculus septentrionalis Poir. Marsh Buttercup. Wet ground, common; *J. Voigt 464.*

Thalictrum dioichm L. Meadow-rue. Rich woods, rare; *J. Ozment.*

CABOMBACEAE A. Gray—Watershield Family

Brasenia schreberi Gmel. Watershield. Swamps, rare; *W. Bailey & J. Swayne 2554.*

Cabomba caroliniana A. Gray. Wolf Lake, occasional; *W. Bailey & J. Swayne 2555.*

NELUMBONACEAE Lindl.—Lotus Family

Nelumbo lutea (Willd.) Pers. American Lotus. Swamps and lakes, common; *W. Stieglitz 47.*

NYMPHAEACEAE DC.—Waterlily Family

Nuphar advena (Ait.) Yellow Pond-lily. Swamps and ponds, common; *W. Stieglitz 23.*

Nymphaea odorata Ait. Fragrant Waterlily. Swamps, rare; *R. Mohlenbrock 12599.*

CERATOPHYLLACEAE A. Gray—Hornwort Family

Ceratophyllum demersum L. Hornwort. Swamps and lakes, occasional; *W. Stieglitz 18.*

BERBERIDACEAE Torr. & Gray—Barberry Family

Caulophyllum thalictroides (L.) Michx. Blue Cohosh. Woods, occasional; *R. Mohlenbrock 12434.*

Podophyllum peltatum L. Mayapple. Woods, common; *R. Mohlenbrock 12867.*

MENISPERMACEAE DC.—Moonseed Family

Calycocarpum lyonii (Pursh) Nutt. Cupseed, Rich woods, rare; *R. Mohlenbrock 12600.*

Cocculus carolinus (L.) DC. Carolina Snailseed. Edge of rich woods, occasional; *Jeffrey s.n.*

Menispermum canadense L. Moonseed. Woods, common; *R. Mohlenbrock 12725.*

LAURACEAE—Laurel Family

Lindera benzoin (L.) Blume. Spice-bush. Mesic slopes and ledges, occasional; *J. Ozment.*

Sassafras albidum (Nutt.) Nees. Sassafras. Rocky slopes and ledges, occasional; *J. Ozment.*

PAPAVERACEAE B. Juss.—Poppy Family

Sanguinaria canadensis L. Bloodroot. Woods, common; *J. Voigt 465.*

Stylophorum diphyllum (Michx.) Nntt, Cleandine Poppy. Rich woods, occasional; *R. Mohlenbrock 905.*

FUMARIACEAE DC.—Fumitory Family

Corydalis flavula (Raf.) DC. Pale Corydalis. Low ground, common; *R. Sands 17.*

Dicentra canadensis (Goldie) Walp. Squirrel Corn. Rich woods, rare; *R. Mohlenbrock s.n.*

Dicentra cucullaria (L.) Bernh. Dutchman's Breeches. Woods, common; *R. Mohlenbrock s.n.*

CRUCIFERAE Juss.—Mustard Family

**Arabidopsis thaliana* (L.) Heynh. Mouse-ear Cress. Waste ground, common; *J. Voigt 1537.*

Arabis laevigata (Muhl.) Poir. Smooth Rockcress. Woods, common; *W. Bailey & J. Swayne 2085.*

Arabis virginica (L.) Poir. Waste ground, common; *R. Mohlenbrock 12650.*

**Armoracia rusticana* (Lam.) Gaertn. Horseradish. Waste ground, rare; *J. Voigt 1737.*

**Barbarea vulgaris* R. Br. Yellow Rocket. Waste ground, common; *R. Mohlenbrock 12427.*

**Brassica juncea* (L.) Cosson. Indian Mustard. Waste ground, occasional; *R. Mohlenbrock 12726.*

**Brassica kaber* (DC.) L. C. Wheeler. Field Mustard. Waste ground, common; *R. Mohlenbrock 12543.*

**Brassica nigra* (L.) Koch. Exposed ledge, rare; *J. Ozment.*

**Capsella bursa-pastoris* (L.) Medic. Shepherd's Purse. Waste ground, common; *R. Mohlenbrock s.n.*

Cardamine arenicola Britt. Small Bittercress. Moist soil, common; *W. Bailey & J. Swayne 1899.*

Cardamine bulbosa (Schreb.) BSP. Bulbous Bittercress. Low woods, common; *W. Bailey & J. Swayne 342.*

Cardamine pennsylvanica Muhl. Wet soil, common; *W. Bailey & J. Swayne 2082.*

Dentaria laciniata Muhl. Toothwort. Woods, common; *J. Voigt 1430.*

Descurainia brachycarpa (Richards.) O. E. Schulz. Tansy Mustard. Along roads, common; *W. Bailey & J. Swayne 2081.*

Draba brachycarpa Nutt. Waste ground, common; *R. Mohlenbrock 12666.*

Iodanthus pinnatifidus (Michx.) Steud. Rich woods, rare; *J. Adams s.n.*

Lepidium campestre (L.) R.Br. Field Peppercress. Waste ground, occasional; *R. Mohlenbrock 12601.*

Lepidium virginicum L. Common Peppergrass. Waste ground, common; *R. Mohlenbrock 12727.*

Nasturtium officinale R.Br. Watercress. Standing water, occasional; *W. Stieglitz 31.*

Neobeckia aquatica (A. Eaton) Greene. Swamps, occasional; *W. Bailey & J. Swayne 2302.*

Rorippa islandica (Oeder) Borbas. Marsh Yellow Cress. Wet ground, common; *R. Mohlenbrock 12667.*

Rorippa sessiliflora (Nutt.) Hitchc. Wet ground, common; *W. Bailey & J. Swayne 918.*

**Sisymbrium officinale* (L.) Scop. Hedge Mustard. Waste ground, common; *J. Voigt 1666.*

**Thlaspi arvense* L. Field Pennycress. Waste ground, common; *W. Bailey & J. Swayne 367.*

Crassulaceae DC.—Stonecrop Family

Penthorum sedoides L. Ditch Stonecrop. Wet ground, common; *R. Mohlenbrock 12651.*

Saxifragaceae DC.—Saxifrage Family

Heuchera hirsuticaulis (Wheelock) Rydb. Alumroot. Rocky woods, common; *R. Mohlenbrock 13900.*

Escalloniaceae Dumort.—Escallonia Family

Itea virginica L. Virginia Willow. Swamps, rare; *W. Bailey & J. Swayne 3046.*

Hydrangeaceae Dumort.—Hydrangea Family

Hydrangea arborescens L. Wild Hydrangea. Woods, common; *R. Mohlenbrock 12987.*

Grossulariaceae Dumort.—Gooseberry Family

Ribes cynosbati L. Pasture Gooseberry. Woods, occasional; *W. Bailey & J. Swayne s.n.*

Hamamelidaceae Lindl.—Witch-hazel Family

Liquidambar styraciflua L. Sweet Gum. Low ground, common; *R. Mohlenbrock 12722.*

Platanaceae Lindl.—Plane-tree Family

Platanus occidentalis L. Sycamore. Low ground, common; *R. Mohlenbrock 12866.*

Rosaceae B. Juss.—Rose Family

Agrimonia parviflora Ait. Moist ground, common; *J. Voigt 1479.*

Agrimonia pubescens Wallr. Woods, common; *J. Voigt 1399.*

Agrimonia rostellata Wallr. Woods, occasional; *R. Mohlenbrock 12986.*

Amelanchier arborea (Michx. f.) Fern. Shadbush. Woods, occasional; *R. Mohlenbrock 12650.*

Aruncus dioicus (Walt.) Fern. Goat's-beard. Woods, occasional; *R. Mohlenbrock 12559.*

Crataegus crusgalli L. Cock-spur Thorn. Woods, common; *R. Mohlenbrock 2169.*

Crataegus mollis (Torr. & Gray) Scheele. Red Haw. Woods, occasional; *W. Bailey & J. Swayne 2089.*

Crataegus pruinosa (Wendl.) K. Koch. Woods, common; *R. Mohlenbrock 12985.*

Crataegus viridis L. Wet ground, occasional; *R. Mohlenbrock 12558.*

Fragaria virginiana Duch. Wild Strawberry. Waste ground, occasional; *J. Voigt s.n.*

Geum canadense Jacq. White Avens. Woods, common; *J. Voigt 1630.*

Geum vernum (Raf.) Torr & Gray. Spring Avens. Woods, common; *R. Mohlenbrock 12436.*

Malus coronaria (L.) Mill. Wild Sweet Crab-apple. Woods, occasional; *J. Voigt 1700.*

Malus ioensis (Wood) Britt. Iowa Crab-apple. Woods, edges of hill prairies, common; *R. Mohlenbrock 12668.*

Potentilla monspeliensis L. Rough Cinquefoil. Wet ground, occasional; *R. Mohlenbrock 12669.*

**Potentilla recta* L. Along roads, occasional; *R. Mohlenbrock 12728.*

Potentilla simplex Michx. Common Cinquefoil. Woods, roadsides, common; *R. Mohlenbrock 902.*

Prunus americana Marsh. Wild Plum. Edges of woods, occasional; *R. Mohlenbrock 12984.*

Prunus hortulana Bailey. Wild Goose Plum. Woods, common; *R. Mohlenbrock 2613.*

Prunus lanata (Sudw.) Mack. & Bush. Woods, occasional; *R. Mohlenbrock 12602.*

Prunus mexicana Wats. Cherty slopes, limestone woods, occasional; *K. Stewart.*

Prunus serotina Ehrh. Wild Black Cherry. Woods, common; *J. Voigt 1701.*

**Pyrus communis* L. Pear. Along roads, occasional; *R. Mohlenbrock 12983.*

Rosa carolina L. Pasture Rose. Woods, along roads, common; *W. Bailey & J. Swayne 2427.*

**Rosa multiflora* Thumb. Multiflora Rose. Along roads, occasional; *R. Mohlenbrock s.n.*

Rosa palustris Marsh. Swamp Rose. Swamps, occasional; *W. Bailey & J. Swayne 1497.*

Rosa setigera Michx. Climbing Rose. Woods, fields, common; *R. Mohlenbrock 12649.*

Rubus allegheniensis Porter. Woods, along roads, common; *R. Mohlenbrock 12982.*

Rubus flagellaris Willd. Dewberry. Fields, common; *J. Bailey & J. Swayne 2083.*

Rubus occidentalis L. Black Raspberry. Woods, common; *J. Voigt 1704.*

Rubus ostryifolius Rydb. High-bush Blackberry. Woods, fields, occasional; *R. Mohlenbrock s.n.*

Rubus pennsylvanicus Poir. Woods, fields, occasional; *R. Mohlenbrock 13437.*

Rubus trivialis Michx. Southern Dewberry. Fields, occasional; *R. Mohlenbrock 12865.*

Leguminosae P. F. Gmel.—Pea Family

Amphicarpa bracteata (L.) Fern. Hog Peanut. Woods, common; *R. Mohlenbrock 12874.*

Apios americana Medic. Woods, occasional; *J. Voigt 1703.*

Apios priceana B. L. Robins. Wolf Lake, very rare; September 8, 1941, *G. D. Fuller 664.*

Cassia fasciculata Michx. Partridge Pea. Woods, fields, common; *J. Voigt 1775.*

Cassia hebecarpa Fern. Along roads, occasional; *R. Mohlenbrock 12648.*

Cassia nictitans L. Woods, fields, occasional; *R. Mohlenbrock 12670.*

Cassia marilandica L. Rich soil along roads, occasional; *R. Sands & D. Drapalik 422.*

Cercis canadensis L. Red Bud. Woods, common; *J. Voigt 1426.*

Crotalaria sagittalis L. Rattle-box. Dry woods, occasional; *R. Mohlenbrock s.n.*

Dalea alopecuroides Willd. Wet waste ground, rare; *R. Mohlenbrock 12671.*

Desmanthus illinoensis (Michx.) MacM. Usually low ground, common; *R. Mohlenbrock 12438.*

Desmodium canadense (L.) DC. Hill prairie, occasional; *J. Voigt 1762.*

Desmodium canescens (L.) DC. Woods, common; *R. Mohlenbrock 12729.*

Desmodium ciliare (Muhl.) DC. Woods, common; *J. Voigt 1546.*

Desmodium cuspidatum (Muhl.) Loud. Woods, occasional; *R. Mohlenbrock 12646.*

Desmodium glabellum (Michx.) DC. Cherty slopes, occasional; *R. Mohlenbrock 12557.*

Desmodium glutinosum (Muhl.) Wood. Moist woods, common; *R. Mohlenbrock 13006.*

Desmodium illinoense A. Gray. Hill prairie, common; *J. Voigt 1591.*

Desmodium laevigatum (Nutt.) DC. Woods, rare; *R. Mohlenbrock 12875.*

Desmodium nudiflorum (L.) DC. Woods, common; *R. Mohlenbrock 12672.*

Desmodium nuttallii (Schindl.) Schubert. Dry woods, occasional; *R. Mohlenbrock 13007.*

Desmodium paniculatum (L.) DC. Woods, common; *R. Mohlenbrock 12439.*

Desmodium pauciflorum (Nutt.) DC. Woods, occasional; *R. Mohlenbrock 12730.*

Desmodium rigidum (Ell.) DC. Dry slopes and ledges, occasional; *J. Ozment.*

Desmodium rotundifolium DC. Woods, occasional; *R. Mohlenbrock 12556.*

Desmodium sessilifolium (Torr.) Torr. & Gray. Woods, occasional; *W. Stieglitz 52.*

Galactia volubilis (L.) Britt. Milk Pea. Dry woods, rare; *R. Mohlenbrock 12555.*

Gleditsia aquatica Marsh. Water Locust. swamps, occasional; *W. Stieglitz 25.*

Gleditsia triacanthos L. Honey Locust. Woods and swamps, common; *R. Mohlenbrock 12646.*

Gymnocladus dioicus (L.) K. Koch. Kentucky Coffee Tree. Woods, occasional; *R. Mohlenbrock 13008.*

Lespedeza bicolor L. Along levee road; *R. Mohlenbrock s.n.*

Lespedeza capitata Michx. Hill prairie, rare; *R. Mohlenbrock 13909.*

**Lespedeza cuneata* (Dum.-Cours.) G. Don. Waste ground, occasional; *R. Mohlenbrock. s.n.*

Lespedeza hirta (L.) Hornem. Cherty slopes, occasional; *R. Mohlenbrock 12731.*

Lespedeza intermedia (S. Wats.) Britt. Cherty slopes, occasional; *R. Mohlenbrock 12732.*

Lespedeza procumbens Michx. Trailing Bush Clover. Woods, common; *R. Mohlenbrock 12440.*

**Lespedeza stipulacea* Maxim. Korean Lespedeza. Along roads, occasional; *R. Mohlenbrock 12645.*

**Lespedeza striata* (Thunb.) Hook. & Arn. Japanese Lespedeza. Along fields and roads, common; *R. Mohlenbrock 12554.*

Lespedeza stuvei Nutt. Woods, occasional; *W. Bailey & J. Voigt 9967.*

Lespedeza violacea (L.) Pers. Dry woods, occasional; *W. Bailey & J. Swayne 2970.*

Lespedeza virginica (L.) Britt. Cherty slopes, common; *G. Fuller 269.*

**Medicago lupulina* L. Black Medic. Waste ground, common; *R. Mohlenbrock 12441.*

**Medicago sativa* L. Alfalfa. Fields and roadsides, common; *R. Mohlenbrock 12644.*

**Melilotus alba* L. White Sweet Clover. Waste ground, common; *R. Mohlenbrock 12426.*

Melilotus officinalis (L.) Lam. Yellow Sweet Clover. Waste ground, common; *R. Mohlenbrock 12425.*

Petalostemum candidum (Willd.) Michx. White Prairie Clover. Hill prairie, occasional; *R. Mohlenbrock 12674.*

Petalostemum purpureum (Vent.) Rydb. Purple Prairie Clover. Hill prairie, occasional; *R. Mohlenbrock & J. Voigt s.n.*

Phaseolus polystachyus (L.) BSP. Wild Kidney Bean. Edge of hill prairie, occasional; *R. Mohlenbrock 12733.*

Psoralea psoralioides (Walt.) Cory. Dry woods, common; *R. Mohlenbrock 12442.*

**Robinia pseudoacacia* L. Black Locust. Along roads, common; *R. Mohlenbrock 12553.*

Strophostyles helvola (L.) Britt. Dry woods, common; *R. Mohlenbrock 12876.*

Strophostyles leiosperma (Torr. & Gray) Piper. Woods, occasional; *R. Mohlenbrock 13910.*

Strophostyles umbellata (Muhl.) Britt. Woods, occasional; *R. Mohlenbrock 12443.*

Stylosanthes biflora (L.) Taub. Dry woods, common; *J. Voigt 684.*

Tephrosia virginiana (L.) Pers. Dry woods, common; *J. Voigt 686.*

Trifolium arvense L. Rabbit-foot Clover. Fields and roadsides, common; *J. Voigt 1682.*

**Trifolium dubium* Sibth. Little Hop Clover. Waste ground, common; *J. Voigt 1537.*

Trifolium hybridum L. Alsike Clover. Waste ground, common; *J. Voigt 1803.*

Trifolium pratense L. Red Clover. Waste ground, common; *J. Voigt 1802.*

**Trifolium procumbens* L. Low Hop Clover. Waste ground, common; *R. Mohlenbrock 12734.*

**Trifolium repens* L. White Clover. Waste ground, common; *J. Voigt 1130.*

**Vicia angustifolia* Reich. Common Vetch. Waste ground, occasional; *R. Mohlenbrock 12675.*

**Vicia cracca* L. Tufted Vetch. Along roads, rare; *J. Voigt 1222.*

**Vicia villosa* Roth. Winter Vetch. Waste ground, common; *J. Voigt 1461.*

GERANIACEAE J. St. Hil.—Geranium Family

Geranium carolinianum L. Cranesbill. Waste ground, common; *R. Mohlenbrock 12444.*

Geranium maculatum L. Wild Geranium. Woods, common; *J. Voigt 1385.*

OXALIDACEAE Lindley—Wood Sorrel Family

Oxalis cymosa Small. Common Wood Sorrel. Waste ground, common; *R. Mohlenbrock 12676.*

Oxalis stricta L. Upright Wood Sorrel. Waste ground, common; *J. Voigt 621.*

Oxalis violacea L. Violet Wood Sorrel. Woods and cherty slopes, common; *R. Mohlenbrock 13911.*

LINACEAE Dumort.—Flax Family

Linum sulcatum Riddell. Dry woods, occasional; *R. Mohlenbrock 13009.*

Linum virginianum L. Dry woods, rare; *R. Mohlenbrock 12735.*

BALSAMINACEAE Dumort.—Balsam Family

Impatiens biflora Walt. Moist soil, common; *W. Stieglitz 39.*

Impatiens pallida Nutt. Pale Touch-me-not. Moist ground, occasional; *R. Mohlenbrock 12445.*

ZYGOPHYLLACEAE Horan.—Caltrop Family

**Tribulus terrestris* L. Puncture-weed. Waste ground, rare; *W. Weber s.n.*

POLYGALACEAE Reichenb.—Milkwort Family

Polygala sanguinea L. Woods, occasional; *J. Voigt 1511.*

EUPHORBIACEAE J. St. Hil.—Spurge Family

Acalypha gracilens A. Gray. Numerous habitats, common; *R. Mohlenbrock 12552.*

Acalypha ostryaefolia Riddell. Edge of swamp, occasional; *J. Voigt 1508.*

Acalypha rhomboidea Raf. Numerous habitats, common; *R. Mohlenbrock 12677.*

Acalypha virginica L. Three-seeded Mercury. Numerous habitats, common; *J. Voigt s.n.*

Chamaesyce humistrata (Engelm.) Small. Edge of swamps, common; *R. Mohlenbrock 12736.*

Chamaesyce maculata (L.) Small. Nodding Spurge. Waste ground, common; *W. Bailey & J. Swayne 3043.*

Chamaesyce serpens (HBK.) Small. Around Wolf Lake, rare; *R. Mohlenbrock 12877.*

Chamaesyce supina (Raf.) Moldenke. Mild Spurge. Waste ground, common; *R. Mohlenbrock 12643.*

Croton capitatus Michx. Sandy soil, occasional; *J. Voigt 1526.*

**Croton glandulosus* L. Sand Croton. Sandy soil, occasional; *J. Voigt 5762.*

Croton monanthogynus Michx. Along roads, occasional; *R. Mohlenbrock 13110.*

Crotonopsis elliptica Willd. Open woods and bluffs, occasional; *R. Mohlenbrock 10211.*

Euphorbia corollata L. Flowering Spurge. A variety of habitats, common; *J. Voigt s.n.*

Euphorbia obtusata Pursh. Base of limestone bluffs, rare; *R. Mohlenbrock 2417.*

**Poinsettia dentata* (Michx.) Small. Roadsides and fields, common; *R. Mohlenbrock 12678.*

Poinsettia heterophylla (L.) Klotzsch & Garcke. Talus slope, rare; *J. Ozment.*

CELASTRACEAE Lindley—Staff-tree Family

Celastrus scandens L. Bittersweet. Woods, common; *R. Mohlenbrock 12737.*

Euonymus atropurpureus Jacq. Wahoo. Moist woods, occasional; *J. Voigt 1152.*

AQUIFOLIACEAE (DC.) Rich.—Holly Family

Ilex decidua Walt. Swamp Holly. Edges of lakes and swamps, common; *W. Bailey & J. Swayne 1023.*

Ilex verticillata (L.) A. Gray. Winterberry. LaRue Swamp, rare.

ANACARDIACEAE Lindley—Sumac Family

Rhus aromatica Ait. Fragrant Sumac. Dry, wooded slopes, common; *W. Bailey & J. Swayne 245.*

Rhus copallina L. Shining Sumac, Fields, along roads, in woods, common; *R. Mohlenbrock 12446.*

Rhus glabra L. Smooth Sumac. Fields, along roads in woods; common; *W. Bailey & J. Swayne 1481.*

Rhus radicans L. Poison Ivy. In a number of habitats, common.

STAPHYLEACEAE (DC.) Lindley—Bladdernut Family

Staphylea trifolia L. Bladdernut. Moist, often calcareous, woods, common; *J. Voigt 1407.*

ACERACEAE J. St. Hil.—Maple Family

Acer drummondii Hooker & Arnott. Swamp Red Maple. Swamps, occasional; *J. Voigt & J. Swayne 1140.*

Acer negundo L. Box Elder. Moist soil, common; *W. Bailey & J. Swayne 339.*

Acer rubrum L. Red Maple. Moist or dry woods, common; *W. Bailey & J. Swayne 2487.*

Acer saccharinum L. Silver Maple. Low, wet ground; common; *R. Mohlenbrock 13912.*

Acer saccharum Marsh. Sugar Maple. Shaded woods, common; *R. Mohlenbrock 13899.*

Acer floridanum (Chapm.) Pax. Southern Sugar Maple. Edge of swamps, rare; *W. Bailey & J. Swayne 2771.*

HIPPOCASTANACEAE Torr. & Gray—Horse-chestnut Family

Aesculus glabra Willd. Ohio Buckeye. Calcareous woods, occasional.

RHAMNACEAE (R. Br.) Horan.—Buckthorn Family

Ceanothus americanus L. New Jersey Tea. Woods, common; *R. Mohlenbrock 12447.*

VITACEAE Lindley—Grape Family

Ampelopsis arborea (L.) Koehne. Pepper-vine. Edge of lakes and swamps, occasional; *R. Mohlenbrock 12721.*

Ampelopsis cordata Michx. Raccoon Grape. Swampy borders, common; *W. Bailey & J. Swayne 12721.*

Parthenocissus quinquefolia (L.) Planch. Virginia Creeper. Woods, common; *R. Mohlenbrock 12878.*

Vitis aestivalis Michx. Summer Grape. Woods, common; *R. Mohlenbrock 12642.*

Vitis cinerea Engelm. Winter Grape. Woods, common; *R. Mohlenbrock 12641.*

Vitis riparia Michx. Riverbank Grape. Low, wet ground, common; *J. Voigt 1971.*

Vitis vulpina L. Frost Grape. Woods, common; *R. Mohlenbrock 12448.*

TILIACEAE Juss.—Linden Family

Tilia americana L. Basswood. Woods, occasional; *R. Mohlenbrock 13111.*

MALVACEAE Necker—Mallow Family

Abutilon theophrastii Medic. Velvet-leaf. Waste ground, common; *R. Mohlenbrock 12449.*

Hibiscus lasiocarpus Cav. Low, wet ground, common; *W. Stieglitz 1.*

Hibiscus militaris Cav. Swampy ground, occasional; *R. Mohlenbrock 13898.*

Sida spinosa L. Waste ground, common; *W. Stieglitz 65.*

HYPERICACEAE Lindley—St. John's-wort Family

Ascyrum multicaule Michx. St. Andrew's Cross. Woods, occasional; *R. Mohlenbrock 12424.*

Hypericum drummondii (Grev. & Hook.) Torr. & Gray. Dry woods and fields, occasional; *R. Mohlenbrock 12679.*

Hypericum gentianoides (L.) BSP. Dry soil, usually on bluffs, occasional; *J. Voigt 3162.*

Hypericum mutilum L. Dwarf St. John's-wort. Along streams and lakes, common; *R. Mohlenbrock 12603.*

Hypericum perforatum L. Common St. John's-wort. Open ground, common; *J. Voigt 733.*

Hypericum prolificum L. Shrubby St. John's-wort. Along Hutchins Creek, occasional; *R. Mohlenbrock 13897.*

Hypericum punctatum Lam. Spotted St. John's-wort. Along roads and in woods, common; *J. Voigt 3060.*

Hypericum sphaerocarpon Michx. Woods, occasional; *J. Voigt s.n.*

Triadenum walteri (Gmel.) Gleason. Around lakes, rare; *W. Stieglitz 13.*

CISTACEAE Horan.—Rockrose Family

Lechea tenuifolia Michx. Sandy soil, common; *R. Mohlenbrock 12423.*

VIOLACEAE DC.—Violet Family

Hybanthus concolor (Forst.) Spreng. Green Violet. Moist woods, common; *J. Voigt 1418.*

Viola eriocarpa Schw. Common Yellow Violet. Woods, common; *R. Sands 20.*

Viola falcata Greene. Woods, common; *R. Mohlenbrock 13112.*

Viola missouriensis Greene. Woods, occasional; *R. Mohlenbrock 11517.*

Viola papilionacea Pursh. Butterfly Violet. Woods, common; *J. Voigt 2612.*

Viola pedata L. Bird-foot Violet. Cherty woods, occasional; *R. Mohlenbrock 13896.*

Viola rafinesquii Greene. Johnny-jump-up. In many habitats, common; *R. Mohlenbrock 12720.*

Viola sagittata Ait. Arrow-leaved Violet. Cherty slopes, rare; *R. Mohlenbrock 15772.*

Viola sororia Willd. Woolly Blue Violet. Woods, common; *J. Voigt 2131.*

Viola striata Ait. White Violet. Moist woods, common; *J. Voigt 1377.*

LYTHRACEAE Lindl.—Loosestrife Family

Ammannia coccinea Rottb. Along lakes and swamps, occasional; *R. Mohlenbrock 12680.*

Cuphea petiolata (L.) Koehne. Waxweed. Moist or dry open soil, occasional; *J. Voigt 2924.*

Decodon verticillatus (L.) Ell. Swamp Loosestrife. In swamps, occasional; *W. Stieglitz 52.*

Lythrum alatum Pursh. Loosestrife. Moist soil, common; *J. Voigt 1987.*

Peplis diandra Nutt. Water Purslane. In swamps, rare.

Rotala ramosior (L.) Koehne. Edge of LaRue Swamp, occasional; *R. Mohlenbrock 13895.*

PASSIFLORACEAE Dumort.—Passion-flower Family

Passiflora lutea L. Passion-flower. Rather dry woods, occasional; *R. Mohlenbrock 12422.*

CACTACEAE Lindley—Cactus Family

Opuntia rafinesquii Engelm. Prickly-pear. Sandy soil above Hutchins Creek, occasional; *R. Mohlenbrock 12640.*

CUCURBITACEAE B. Juss.—Gourd Family

Sicyos angulatus L. Bur. Cucumber. Below limestone bluffs, occasional; *R. Mohlenbrock 12719.*

ONAGRACEAE Dumort.—Evening Primrose Family

Circaea latifolia Hill. Enchanter's Nightshade. Low ground in woods, common; *J. Voigt 3002.*

Epilobium coloratum Muhl. Willow Herb. Moist ground, common; *W. Stieglitz 6.*

Jusiaea decurrens (Walt. DC.) In swamps, rare; *W. Bailey & J. Swayne 14810.*

Jussiaea diffusa Forskal. Primrose Willow. In lakes and swamps, common; *J. Voigt 761.*

Ludwigia alternifolia L. Seedbox. Wet ground, common; *W. Stieglitz 53.*

Ludwigia palustris (L.) Ell. Edge of swamps, occasional; *W. Stieglitz 38.*

Oenothera biennis L. Common Evening Primrose. Numerous habitats, common; *R. Mohlenbrock 12551.*

Oenothera laciniata Hill. Waste ground, common; *R. Mohlenbrock 12864.*

Oenothera linifolia Nutt. Thread-leaved Sundrops. Dry soil on bluffs, rare; *W. Bailey & J. Swayne 2419.*

**Oenothera speciosa* Nutt. White Evening Primrose. Waste ground, occasional; *R. Mohlenbrock 12981.*

**Oenothera strigosa* (Rydb.) Mack & Bush. Waste ground, rare; *R. Mohlenbrock 13913.*

HALORAGACEAE Horan.—Water Milfoil Family

Proserpinaca palustris L. In swamps, rare; *R. Mohlenbrock 12451.*

CALLITRICHACEAE Lindley—Water Starwort Family

Callitriche heterophylla Pursh. In stagnant water, occasional; *R. Mohlenbrock 12681.*

Callitriche palustris L. Swamps, rare; *R. Mohlenbrock* 2714.

Callitriche terrestris Raf. Moist ground, common; *R. Mohlenbrock 12738.*

CORNACEAE Link—Dogwood Family

Cornus drummondii C. A. Mey. Rough-leaved Dogwood. Edges of woods, common; *J. Voigt 1160.*

Cornus florida L. Flowering Dogwood. Woods, common; *W. Bailey & J. Swayne 345.*

Cornus foemina Mill. Swampy woods, occasional; *R. Mohlenbrock 12604.*

Cornus obliqua Raf. Pale Dogwood. Low woods, occasional; *W. Bailey & J. Swayne 2294.*

Cornus racemosa Lam. Gray Dogwood. Woods, common; *W. Bailey & J. Swayne 2383.*

Nyssa sylvatica Marsh. Sour Gum. Woods, common; *R. Mohlenbrock 12879.*

ARALIACEAE Vent.—Ginseng Family

Aralia racemosa L. American Spikenard. Moist woods, occasional; *R. Mohlenbrock 13113.*

Aralia spinosa L. Hercules' Club. Woods, occasional; *R. Mohlenbrock 13894.*

Panax quinquefolius L. Ginseng. Woods, occasional; *E. Stadelbacher s.n.*

UMBELLIFERAE Scop.—Carrot Family

**Anethum graveolens* L. Dill. Waste ground; *R. Mohlenbrock 12421.*

Chaerophyllum procumbens (L.) Chervil. Waste ground, common; *R. Mohlenbrock 12639.*

Chaerophyllum tainturieri Hook. Hairy Chervil. Waste ground, common; *R. Mohlenbrock 12718.*

Cicuta maculata L. Water Hemlock. Around swamps, occasional; *W. Stieglitz 49.*

Cryptotaenia canadensis (L.) DC. Honewort. Woods, common; *R. Mohlenbrock 12550.*

**Daucus carota* L. Wild Carrot. Waste ground, common; *J. Voigt 2672.*

Erigenia bulbosa (Michx.) Nutt. Harbinger-of-spring. Deep woods, occasional; *R. Mohlenbrock 12863.*

Osmorhiza claytonii (Michx.) Clarke. Sweet Cicely. Woods, common; *R. Mohlenbrock 12980.*

Osmorhiza longistylis (Torr.) DC. Sweet Cicely. Woods, occasional; *J. Voigt 3013.*

Pastinaca sativa L. Parsnip. Waste ground, occasional; *R. Mohlenbrock 13914.*

Polytaenia nuttallii DC. Prairie Parsley. Hill prairie, rare; *J. Voigt 2916.*

Ptilimnium costatum (Ell.) Raf. Edges of swamps, rare; *R. Mohlenbrock 12452.*

Sanicula canadensis L. Short-styled Snakeroot. Woods, common; *J. Voigt 2221.*

Sanicula gregaria Bickn. Common Snakeroot. Woods, common; *J. Voigt 2220.*

Sium suave Walt. Water Parsnip. Around swamps, occasional; *R. Mohlenbrock 12682.*

Taenidia integerrima (L.) Drude. Along road, rare; *J. Voigt 1356.*

Thaspium trifoliatum (L.) A. Gray. Meadow Parsnip. Woods, common; *R. Mohlenbrock 12739.* The purple-flowered form also occurs occasionally.

**Torilis japonica* (Houtt.) DC. Hedge Parsley. Waste ground, occasional; *R. Mohlenbrock 12739.*

Ericaceae DC.—Heath Family

Monotropa uniflora L. Indian Pipe. Deep woods, occasional; *W. Bailey & J. Swayne 1838.* Pink plants sometimes occur.

Rhododendron roseum (Loisel.) Rehd. Cherty slopes, rare; *W. Bailey & J. Swayne 34.*

Vaccinium arboreum Marsh. Farkleberry. Dry, cherty woods, common; *J. Voigt 1357.*

Vaccinium vacillans Torr. Hill Blueberry. Dry, Cherty woods, common; *R. Mohlenbrock 12605.*

Ebenaceae Vent.—Ebony Family

Diospryros virginiana L. Persimmon. Woods, common; *W. Bailey & J. Swayne 420.*

Primulaceae Vent.—Primrose Family

Androsace occidentalis Pursh. On limestone bluffs, rare.

Dodecatheon meadia L. Shooting Shar. Dry woods, common; *J. Voigt 1410.*

Lysimachia ciliata L. Fringed Loosestrife. Wet ground, common; *J. Voigt 1168.*

Lysimachia lanceolata Walt. Woods, common; *R. Mohlenbrock 12880.*

Lysimachia nummularia L. Moneywort. Around Wolf Lake, occasional; *W. Bailey & J. Swayne 2481.*

Samolus parviflorus Raf. Brookweed. Damp ground, occasional; *J. Voigt 1713.*

Oleaceae Lindley—Olive Family

Forestiera acuminata (Michx.) Poir. Wet ground, occasional; *R. Mohlenbrock 13114.*

Fraxinus americana L. White Ash. Woods, common; *G. Gunning s.n.*

Fraxinus lanceolata Borkh. Green Ash. Shaded woods, common; *R. Mohlenbrock 13893.*

Fraxinus pennsylvanica Marsh. Red Ash. In swamps, occasional; *R. Mohlenbrock 12420.*

Fraxinus quadrangulata Michx. Blue Ash. Limestone cliffs, rare; *R. Mohlenbrock 11086.*

Fraxinus tomentosa Michx. Pumpkin Ash. In deep swamps, rare; *R. Mohlenbrock 12638.*

Loganiaceae Dumort.—Logania Family

Spigelia marilandica L. Indian Pink. Woods, occasional; *J. Voigt 1919.*

Gentianaceae Dumort.—Gentian Family

Sabatia angularis (L.) Pursh. Moist soil, occasional; *R. Mohlenbrock 12449.*

Apocynaceae Lindley—Dogbane Family

Amsonia tabernaemontana Walt. Around swamps and lakes, occasional; *J. Voigt 2320.*

Apocynum androsaemifolium L. Spreading Dogbane. Woods, common; *R. Mohlenbrock 12862.*

Apocynum cannabinum L. Hemp Dogbane. Fields and woods, common; *R. Mohlenbrock 12979.*

Apocynum pubescens R.Br. Velvet Dogbane. Fields, common; *J. Voigt s.n.*

Apocynum sibiricum Jacq. Dogbane. Fields, occasional; *J. Voigt s.n.*

Trachelospermum difforme (Walt.) A. Gray. Around swamps, rare; *R. Mohlenbrock s.n.*

Asclepiadaceae Lindley—Dogbane Family

Aceratcs lanuginosa (Nutt.) Dec. Edge of hill prairie, rare; *R. Mohlenbrock 13915.*

Acerates viridiflora (Raf.) Eaton. Hill prairie, rare; *R. Mohlenbrock 12453.*

Ampelamus albidus (Nutt.) Britt. Bluevine. Woods, common; *J. Voigt 3410.*

Asclepias exaltata L. Poke Milkweed. Moist woods, rare; *R. Mohlenbrock s.n.*

Asclepias incarnata L. Swamp Milkweed. Wet ground, common; *R. Mohlenbrock 12683.*

Asclepias perennis Walt. Wet woods, occasional; *W. Bailey & J. Swayne 2702.*

Asclepias purpurascens L. Purple Milkweed. Along roads, rare; *R. Mohlenbrock 12740.*

Asclepias quadrifolia Jacq. Dry, cherty woods, occasional; *R. Mohlenbrock 12606.*

Asclepias syriaca L. Common Milkweed. Fields and roadsides, common; *R. Mohlenbrock 12881.*

Asclepias tuberosa L. Butterfly Weed. Hill prairies and woods, common; *W. Bailey & J. Swayne 1479.*

Asclepias verticillata L. Horsetail Milkweed. Dry woods, occasional; *R. Mohlenbrock 13115.*

Gonolobus gonocarpos (Walt.) Perry. Climbing Milkweed. Woods, rare; *W. Stieglitz 67.*

CONVOLVULACEAE Vent.—Morning-glory Family

Convolvulus americanus (Sims) Greene. Fields, common; *W. Bailey 571.*

Convolvulus arvensis L. Field Bindweed. Fields, common; *R. Mohlenbrock 14077.*

Cuscuta compacta Juss. Edge of swamps, common; *W. Bailey & J. Swayne 3058.*

Cuscuta cuspidata Engelm. Woods and roadsides, common; *J. Voigt 2828.*

Cuscuta gronovii Willd. Woods, occasional; *R. Mohlenbrock 13892.*

Cuscuta pentagona Engelm. Woods, rare.

Cuscuta polygonorum Engelm. Edge of swamp, occasional; *J. Voigt 1875.*

**Ipomoea hederacea* Jacq. Ivy-leaved Morning-glory. Fields, common; *R. Mohlenbrock 12419.*

Ipomoea lacunosa L. Small-flowered Morning-glory. Edge of swamps and lakes, common; *R. Mohlenbrock 15029.*

Ipomoea pandurata (L.) Meyer. Wild Sweet Potato. Fields and along roads, common; *R. Mohlenbrock 12637.*

**Ipomoea purpurea* (L.) Roth. Common Morning-glory. Fields, common; *W. Bailey & J. Swayne 3043.*

Quamoclit coccinea (L.) Moench. Red Morning-glory. Along a road, rare; *W. Bailey & J. Swayne 1831.*

POLEMONIACEAE Juss.—Phlox Family

Phlox bifida Beck. Cleft Phlox. Woods and cliffs, common; *R. Sands 19.*

Phlox divaricata L. Blue Phlox. Woods, common; *R. Sands 16.*

Phlox glaberrima L. Smooth Phlox. Open woods, occasional; *J. Voigt 1048.*

Phlox paniculata L. Garden Phlox. Moist soil, occasional; *J. Voigt 2404.*

Phlox pilosa L. Downy Phlox. Woods, common; *R. Mohlenbrock 12716.*

Polemonium reptans L. Jacob's-ladder. Moist woods, common; *J. Voigt 2509.*

HYDROPHYLLACEAE Lindley—Waterleaf Family

Hydrolea affinis A. Gray. Edges of swamps and lakes, occasional; *W. Bailey & J. Swayne 1460.*

Hydrophyllum appendiculatum Michx. Moist woods, common; *R. Mohlenbrock 12448.*

Hydrophyllum virginianum L. Waterleaf. Moist woods, common; *R. Mohlenbrock 12861.*

Phacelia bipinnatifida Michx. Moist woods, common; *R. Mohlenbrock 12978.*

Phacelia purshii Buckley. Low woods, common; *J. Voigt 1050.*

Phacelia ranunculacea (Nutt.) Constance. Low woods, occasional; *J. Voigt 1411.*

BORAGINACEAE Lindley—Borage Family

**Cynoglossum officinale* L. Common Hound's-tongue. Fields, occasional; *R. Mohlenbrock 13916.*

Cynoglossum virginianum L. Wild Comfrey. Woods, occasional; *R. Mohlenbrock 12454.*

Hackelia virginiana (L.) I. M. Johnston. Stickseed. Woods, common; *R. Mohlenbrock 12684.*

**Heliotropium indicum* L. Heliotrope. Moist waste ground, occasional; *R. Mohlenbrock 12741.*

**Lithospermum arvense* L. Field Gromwell. Waste ground, common; *R. Mohlenbrock 7164.*

Lithospermum canescens (Michx.) Lehm. Hoary Gromwell. Bluffs, rare; *R. Mohlenbrock 12697.*

Lithospermum latifolium Michx. American Gromwell. Dry woods, occasional; *J. Voigt 3111.*

Mertensia virginica (L.) Pers. Bluebells. Woods, occasional; *J. Voigt & W. Welch 526.*

Myosotis macrosperma Engelm. Forget-me-not. Woods, occasional; *R. Mohlenbrock 13116.*

Myosotis verna Nutt. Woods and fields, common; *R. Mohlenbrock 12882.*

Verbenaceae Juss.—Vervain Family

Phryma leptostachya L. Lopseed. Moist woods, occasional; *R. Mohlenbrock 13891.*

Phyla lanceolata (Michx.) Greene. Frog-fruit. Low areas, common; *J. Voigt 682.*

Verbena bracteata Lag. & Rodr. Waste ground, common; *J. Voigt 1870.*

Verbena canadensis (L.) Britt. Woods, occasional; *J. Voigt s.n.*

Verbena hastata L. Blue Vervain. Woods and along roads, common; *R. Mohlenbrock 12418.*

Verbena simplex Lehm. Narrow-leaved Vervain. Open ground, common; *R. Mohlenbrock 12636.*

Verbena stricta Vent. Hoary Vervain. Open ground, common; *J. Voigt s.n.*

Verbena urticifolia L. White Vervain. Woods and along roads, common; *W. Stieglitz.*

Labiatae B. Juss.—Mint Family

Agastache nepetoides (L.) Kuntze. Open woods, occasional; *J. Voigt 2727.*

Blephilia ciliata (L.) Benth. Wood Mint. Woods, common; *R. Mohlenbrock 12715.*

Blephilia hirsuta (Pursh) Benth. Woods, occasional; *J. Voigt 3002.*

Collinsonia canadensis L. Richweed. Moist woods, rare; *R. Mohlenbrock 12447.*

Cunila origanoides (L.) Britt. Stone Mint. Wooded ridges, common; *G. Fuller 258.*

**Glecoma heterophylla* Waldst. & Kit. Small Ground Ivy. Moist waste ground, occasional; *R. Mohlenbrock 12860.*

Hedeoma pulegioides (L.) Pers. American Pennyroyal. Dry woods, occasional; *R. Mohlenbrock 12977.*

Isanthus brachiatus (L.) BSP. False Pennyroyal. On bluffs and in dry woods, occasional; *R. Mohlenbrock 13917.*

**Lamium amplexicaule* L. Henbit. Waste ground, common; *R. Mohlenbrock 11579.*

**Lamium purpureum* L. Purple Dead Nettle. Waste ground, occasional; *R. Mohlenbrock 12455.*

**Leonorus cardiaca* L. Talus slopes and low ledges, rare; *J. Ozment.*

Lycopus americanus Muhl. Wet ground, common; *R. Mohlenbrock 12685.*

Lycopus rubellus Moench. Water Horehound. Wet ground or in water, common; *W. Stieglitz 19.*

Lycopus virginicus L. Wet ground, common; *J. Voigt 2431.*

**Marrubium vulgare* L. Common Horehound. Waste ground, rare; *collector unknown.*

**Mentha arvensis* L. Field Mint. Waste ground; *W. Stieglitz 14.*

Mentha canadensis L. Wild Mint. Moist soil, occasional; *R. Mohlenbrock 12742.*

**Mentha piperita* L. Peppermint. Waste ground, rare; *R. Mohlenbrock s.n.*

**Mentha spicata* L. Spearmint. Waste ground, rare; *R. Mohlenbrock s.n.*

Monarda bradburiana Beck. Bee Balm. Dry woods, common; *W. Bailey & J. Swayne 2240.*

Monarda fistulosa L. Wild Bergamot. Woods, common; *R. Mohlenbrock 12608.*

**Nepeta cataria* L. Catnip. Waste ground, occasional; *R. Mohlenbrock s.n.*

**Perilla frutescens* (L.) Britt. Beef-steak Plant. Moist, waste ground; common; *J. Voigt 4171.*

Physostegia virginiana (L.) Benth. Moist soil, occasional; *G. Fuller 243.*

Prunella vulgaris L. Self-heal. Waste ground, common; *R. Mohlenbrock 12803.*

Pycnanthemum flexuosum (Walt.) BSP. Mountain Mint. Dry woods, common; *R. Mohlenbrock 13117.*

Pycnanthemum incanum (L.) Michx. Dry soil, rare; *J. Voigt s.n.*

Pycnanthemum pycnanthemoides (Leavenw.) Fern. Dry woods and along roads, occasional; *R. Mohlenbrock 13890.*

Salvia lyrata L. Cancer-weed. Rocky woods, rare; *J. Voigt 2114.*

Scutellaria elliptica Muhl. Hairy Skullcap. Woods, rare; *R. Mohlenbrock 12417.*

Scutellaria incana Biehler. Downy Skullcap. Woods, occasional; *J. Voigt 1490.*

Scutellaria lateriflora L. Moist soil, common; *W. Bailey & J. Swayne 2774.*

Scutellaria nervosa Pursh. Low, wet woods, rare; *W. Bailey & J. Swayne 2303*

Scutellaria ovata Hill. Heart-leaved Skullcap. Woods, occasional; *R. Mohlenbrock 294.*

Scutellaria parvula Michx. Rocky woods, rare; *J. Voigt 2716.*

Stachys tenuifolia Willd. Hedge Nettle. Wet soil, occasional; *R. Mohlenbrock 13889.*

Teucrium canadense L. Wood Sage. Moist ground, common; *R. Mohlenbrock 12416.*

Solanaceae Pers.—Potato Family

Datura stramonium L. Jimson-weed. Waste ground, common; *R. Mohlenbrock 12655.*

Physalis heterophylla Nees. Edge of fields, common; *J. Voigt s.n.*

Physalis lanceolata Michx. Dry waste ground, rare; *R. Mohlenbrock & J. Voigt 9965.*

Physalis pruinosa L. Moist soil, occasional; *C. Bollwinkel s.n.*

Physalis pubescens L. Waste ground, occasional; *R. Mohlenbrock 12714.*

Physalis subglabrata Mack. & Bush. Smooth Ground Cherry. Waste ground, common; *R. Mohlenbrock 12446.*

Physalis virginiana Mill. Ground Cherry. Waste ground, common; *J. Voigt s.n.*

Solanum carolinense L. Horse Nettle. Waste ground, common; *R. Mohlenbrock 12976.*

Solanum nigrum L. Black Nightshade. Moist waste ground, common; *J. Voigt 3121.*

Scrophulariaceae Lindley—Figwort Family

Aureolaria flava (L.) Farwell. False Foxglove. Open woods, occasional; *R. Mohlenbrock 12634.*

Bacopa rotundifolia (Michx.) Wettst. Edge of lakes, rare; *J. Voigt 2199.*

Dasistoma macrophylla (Nutt.) Raf. Mullein Foxglove. Dry woods, occasional; *R. Mohlenbrock 583.*

Gerardia tenuifolia Vahl. Rather moist soil, common; *R. Mohlenbrock 13918.*

Gratiola neglecta Torr. Moist soil, common; *R. Mohlenbrock 12456.*

Gratiola virginiana L. Edge of swamp, rare; *J. Voigt s.n.*

Leucospora multifida (Michx.) Nutt. Along Hutchins Creek, occasional; *J. Voigt 2629.*

Lindernia anagallidea (Michx.) Pennell. Moist ground, occasional; *J. Voigt s.n.*

Lindernia dubia (L.) Pennell. Wet soil, common; *R. Mohlenbrock 12713.*

Mimulus alatus Ait. Monkey Flower. Wet soil, common; *G. Fuller 233.*

Mimulus ringens L. Around swamps, rare; *R. Mohlenbrock 12445.*

Penstemon alluviorum Pennell. Edge of wet woods, rare; *R. Mohlenbrock s.n.*

Penstemon calycosus Small. Rich soil, rare; *R. Mohlenbrock 12858.*

Penstemon digitalis Nutt. Foxglove Penstemon. Woods, common; *R. Mohlenbrock 12975.*

Penstemon hirsutus (L.) Willd. Talus at base of limestone bluffs, rare; *W. Bailey & J. Swayne 2314.*

Penstemon pallidus Small woods, common; *R. Mohlenbrock 12686.*

Penstemon tubaeflorus Nutt. Along roads, rare; *W. Bailey & J. Swayne 2315.*

Scrophularia marilandica L. Figwort. Woods, occasional; *R. Mohlenbrock 12743.*

**Verbascum blattaria* L. Moth Mullein. Waste ground, occasional; *J. Voigt 1119.*

**Verbascum thapsus* L. Common Mullein. Waste ground, common; *R. Mohlenbrock 12609.*

**Veronica arvensis* L. Speedwell. Waste ground, common; *R. Mohlenbrock 12884.*

Veronica peregrina L. Waste ground, common; *R. Mohlenbrock 13118.*
Veronicastrum virginicum (L) Farwell. Culver-root. Woods, occasional; *J. Voigt 1494.*

ACANTHACEAE J. St. Hil.—Acanthus Family

Dianthera americana L. Water Willow. In Hutchins Creek, rare; *J. Voigt 2215.*
Ruellia humilis Nutt. Hairy Ruellia. Woods, common; *R. Mohlenbrock 13888.*
Ruellia pedunculata Torr. Stalked Ruellia. Dry woods, occasional; *J. Voigt 2008.*
Ruellia strepens L. Smooth Ruellia. Rich soil in woods, occasional; *R. Mohlenbrock 8879.*

LENTIBULARIACEAE Lindley—Bladderwort Family

Utricularia gibba L. Shallow swamp water, rare; *J. Voigt 2211.*
Utricularia vulgaris L. Shallow swamp water, occasional; *J. Voigt 2212.*

OROBANCHACEAE Lindl.—Broomrape Family

Epifagus virginiana (L.) Barton. Beech Drops. On beech roots, common; *R. Mohlenbrock 12415.*
Orobanche uniflora L. Open woods, occasional; *M. Pulliam 1.*

BIGNONIACEAE Pers.—Bignonia Family

Campsis radicans (L.) Seem. Trumpet Creeper. Woods and fields, common; *R. Mohlenbrock 12633.*

PLANTAGINACEAE Lindley—Plantain Family

Plantago aristata Michx. Bracted Plantain. Fields, common; *R. Mohlenbrock 12712.*
**Plantago lanceolata* L. Buckhorn Plantain. Waste ground, common; *J. Voigt 2601.*
Plantago pusilla Nutt. Waste ground, common; *R. Mohlenbrock 12444.*
Plantago rugelii Dec. Common Plantain. Waste ground; *R. Mohlenbrock 11651.*
Plantago virginica L. Waste ground, common; *R. Mohlenbrock 12857.*

RUBIACEAE B. Juss.—Madder Family

Cephalanthus occidentalis L. Buttonbush. In water, common; *W. Stieglitz 21.*
Diodia teres Walt. Rough Buttonweed. Fields, common; *R. Mohlenbrock 162.*
Diodia virginiana L. Buttonweed. Edge of swamp, rare; *J. Voigt s.n.*
Galium aparine L. Goosegrass. Woods, common; *R. Mohlenbrock 12974.*
Galium circaezans Michx. Wild Licorice. Woods, common; *R. Mohlenbrock s.n.*
Galium concinnum Torr. & Gray. Dry woods, common; *R. Mohlenbrock 13919.*
Galium obtusum Bigel. Moist ground, common; *W. Bailey & J. Swayne 2304.*
Galium pilosum Ait. Woods, occasional; *R. Mohlenbrock 12457.*
Galium tinctorium L. On decayed vegetation in swamps, rare; *W. Stieglitz 2.*
Galium triflorum Michx. Sweet-scented Bedstraw. Low woods, common; *J. Voigt 2820.*
Houstonia lanceolata (Poir.) Britt. Hill prairies, occassional; *J. Voigt 636.*
Houstonia nigricans (Lam.) Fern. Limestone ledges, rare; *R. Mohlenbrock 15037.*
Houstonia pusilla Schoepf. Bluets. Woods and bluffs, common; *R. Mohlenbrock 12687.*
Houstonia tenuifolia Nutt. Rocky woods, occasional; *R. Mohlenbrock 12744.*
Spermacoce glabra Michx. Smooth Buttonweed. Wet soil, common; *R. Mohlenbrock s.n.*

CAPRIFOLIACEAE Vent.—Honeysuckle Family

**Lonicera japonica* Thumb. Japanese Honeysuckle. Disturbed areas, common; *R. Mohlenbrock 12610.*
Sambucus canadensis L. Elderberry. Numerous situations, common; *R. Mohlenbrock 12885.*
Symphoricarpos orbiculatus Moench. Coralberry. Edge of woods, common; *J. Voigt s.n.*
Triosteum angustifolium L. Horse Gentian. Rich soil, rare; *R. Mohlenbrock 13119.*
Viburnum prunifolium L. Black Haw. Woods, occasional; *R. Mohlenbrock 12707.*

Viburnum recognitum Fern. Woods, occasional; *R. Mohlenbrock 12628.*
Viburnum rufidulum Raf. Southern Black Haw. Woods, occasional; *R. Mohlenbrock 12439.*

CAMPANULACEAE Juss.—Bellflower Family

Campanula americana L. Bellflower. Woods, common; *R. Mohlenbrock 12852.*
Triodanis biflora (R. & P.) Greene. Exposed ledges, rare; *J. Ozment.*
Triodanis perfoliata (L.) Nieuwl. Dry soil and waste ground, common; *R. Mohlenbrock 12969.*

LOBELIACEAE Juss.—Lobelia Family

Lobelia cardinalis L. Cardinal Flower. Wet soil, occasional; *R. Mohlenbrock 12462.*
Lobelia inflata L. Indian Tobacco. Woods and fields, common; *R. Mohlenbrock 12749.*
Lobelia leptostachys A. DC. Cherty slopes, rare; *R. Mohlenbrock 12615.*
Lobelia puberula Michx. Downy Lobelia. Wet ground, occasional; *R. Mohlenbrock 12890.*
Lobelia siphilitica L. Blue Cardinal Flower. Wet soil, occasional; *J. Voigt s.n.*
Lobelia spicata Lam. Cherty slopes, rare; *R. Mohlenbrock s.n.*

VALERIANACEAE Batsch—Valerian Family

Valerianella radiata (L.) Dufr. Wet areas, common; *R. Mohlenbrock 13124.*

COMPOSITAE P. F. Gmel.—Sunflower Family

**Achillea millefolium* L. Yarrow. Waste ground, common; *R. Mohlenbrock 13882.*
Ambrosia artemisiifolia L. Common Ragweed. Waste ground; common; *R. Mohlenbrock 12409.*
Ambrosia bidentata Michx. Western Ragweed. Fields, occasional; *R. Mohlenbrock 12627.*
Ambrosia trifida L. Giant Ragweed. Waste ground, common; *R. Mohlenbrock 12706.*
Antennaria fallax Greene. Dry woods, occasional; *J. Voigt s.n.*
Antennaria plantaginifolia (L.) Hook. Pussy-toes. Dry woods and cherty slopes, common; *R. Mohlenbrock 11585.*
**Anthemis cotula* L. Dog Fennel. Waste ground, occasional; *R. Mohlenbrock 12463.*
**Arctium minus* (Hill) Bernh. Common Burdock. Waste ground, rare; *W. Bailey & J. Swayne 2699.*
**Artemisia annua* L. Annual Wormwood. Moist, waste ground, rare; *R. Mohlenbrock 12891.*
Aster anomalus Engelm. Rocky woods, occasional; *R. Mohlenbrock 15156.*
Aster drummondii Lindl. Dry woods, occasional; *J. Voigt 3191.*
Aster exiguus (Fern.) Rydb. Dry soil, occasional; *W. Bailey & J. Swayne 3191.*
Aster laevis L. Smooth Aster. Along Hutchins Creek, rare; *J. Voigt 2612.*
Aster lateriflorus (L.) Britt. Moist soil, occasional; *W. Stieglitz 12.*
Aster oblongifolius Nutt. Woods near edges of bluffs, occasional; *W. Bailey & J. Swayne 231.*
Aster ontarionis Wieg. Wet ground, common; *R. Mohlenbrock s.n.*
Aster patens Ait. Dry woods, common; *J. Voigt 3188.*
Aster pilosus Willd. Open areas, common; *R. Mohlenbrock 13125.*
Aster praealtus Poir. Wet ground, occasional; *R. Mohlenbrock 12750.*
Aster salicifolius Lam. Wet ground, occasional; *W. Stieglitz 62.*
Aster sagittifolius Wedem. Woods, common; *W. Bailey & J. Swayne 233.*
Aster shortii Lindl. Dry woods, occasional; *W. Bailey & J. Swayne 232.*
Aster simplex Willd. Moist areas, common; *W. Bailey & J. Swayne 3214.*
Aster turbinellus Lindl. Rocky woods, occasional; *J. Voigt 3192.*
Aster vimineus Lam. Fields, occasional; *W. Bailey & J. Swayne 1792.*
Bidens aristosa (Michx.) Britt. Moist ground, common; *R. Mohlenbrock 12616.* Var. *fritcheyi* Fern. also occurs in the area.
Bidens bipinnata L. Spanish Needles. Fields and woods, common; *R. Mohlenbrock 12438.*
Bidens cernua L. Begger Ticks. Wet ground, occasional; *R. Mohlenbrock 12693.*
Bidens comosa (A. Gray) Wieg. Wet soil, common; *W. Bailey & J. Swayne 3243.*

Bidens connata Muhl. Swamp Beggar Ticks. Wet ground, occasional; *W. Bailey & J. Swayne 3037.*

Bidens discoidea (Torr. & Gray) Britt. Wet ground, occasional; *W. Bailey & J. Swayne 1782.*

Bidens frondosa L. Fields, common; *W. Stieglitz 54.*

Bidens polylepis Blake. Wet ground, rare; *W. Bailey & J. Swayne 1694.*

Bidens vulgata Greene. Tall Beggar Ticks. Fields, occasional; *R. Mohlenbrock 12968.*

Boltonia asteroides (L.) L'Her. Moist areas, occasional; *J. Voigt s.n.*

Cacalia atriplicifolia L. Indian Plantain. Dry woods, occasional; *R. Mohlenbrock 290.*

Cacalia muhlenbergii (Schultz-Bip.) Fern. Woods, occasional; *R. Mohlenbrock 13925.*

**Centaurea cyanus* L. Bachelor's Buttons. *W. Bailey & J. Swayne 1490.*

**Chrysanthemum leucanthemum* L. Ox-eye Daisy. Fields, common; *R. Mohlenbrock 12851.*

Cichorium intybus L. Chicory. Along levee road, occasional; *R. Mohlenbrock s.n.*

Cirsium altissimum (L.) Spreng. Tall Thistle. Woods, occasional; *R. Mohlenbrock 14021.*

Cirsium discolor (Muhl.) Spreng. Field Thistle. Rich soil, occasional; *R. Mohlenbrock 12751.*

**Cirsium vulgare* (Savi) Airy-Shaw. Bull Thistle. Fields, common; *R. Mohlenbrock 12437.*

Coreopsis tripteris L. Tall Tickweed. Woods, occasional; *R. Mohlenbrock 12892.*

Echinacea pallida Nutt. Hill prairie, rare; *R. Mohlenbrock & J. Voigt 8859.*

Eclipta alba (L.) Hassk. Wet ground, common; *W. Stieglitz 48.*

Elephantopus carolinianus Willd. Elephant's-foot. Woods, occasional; *R. Mohlenbrock 12626.*

Erechtites hieracifolia (L.) Raf. Fireweed. Fields and moist open areas, occasional; *R. Mohlenbrock 13881.*

Erigeron annuus (L.) Pers. Whitetop. Woods and fields, common; *W. Bailey & J. Swayne 419.*

Erigeron canadensis L. Muletail. Waste ground, common; *R. Mohlenbrock 12617.*

Erigeron divaricatus Michx. Dry soil, occasional; *R. Mohlenbrock 12618.*

Erigeron philadelphicus L. Fleabane. Woods and fields, common; *R. Mohlenbrock 12408.*

Erigeron pulchellus Michx. Woods, occasional; *R. Mohlenbrock 13126.*

Erigeron strigosus Muhl. Daisy Fleabane. Woods and fields, common; *W. Bailey & J. Swayne 1488.*

Eupatorium altissimum L. Honeyweed. Moist woods, common; *W. Bailey & J. Swayne 893.*

Eupatorium coelestinum L. Moist-flower. Wet ground, common; *W. Bailey & J. Swayne 1795.*

Eupatorium perfoliatum L. Boneset. Wet ground, common; *R. Mohlenbrock 12464.*

Eupatorium purpureum L. Joe-pye Weed. Woods, common; *R. Mohlenbrock 12407.*

Eupatorium rugosum Houtt. White Snakeroot. Woods, common; *R. Mohlenbrock 12967.*

Eupatorium serotinum Michx. Late Boneset. Moist ground, common; *J. Voigt 3102.*

Eupatorium sessilifolium L. Upland Boneset. Woods, occasional; *W. Bailey & J. Swayne 885.*

Gnaphalium obtusifolium L. Sweet Everlasting. Woods and fields, common; *J. Voigt 5025.*

Gnaphalium purpureum L. Cudweed. Fields, occasional; *J. Voigt s.n.*

Helenium autumnale L. Sneezeweed. Wet ground, common; *J. Voigt 2913.*

Helenium nudiflorum Nutt. Fields, occasional; *R. Mohlenbrock 12694.*

Helenium tenuifolium Nutt. Bitterweed. Dry waste ground, occasional; *R. Mohlenbrock 12625.*

Helianthus decapetalus L. Dry woods, occasional; *R. Mohlenbrock s.n.*

Helianthus divaricatus L. Dry woods, common; *W. Bailey & J. Swayne 27054.*

Helianthus grosseserratus Martens. Fields and along roads, common; *R. Mohlenbrock 12705.*

Helianthus hirsutus Raf. Fields, occasional; *R. Mohlenbrock 12850.*

Helianthus microcephalus Torr. & Gray. Dry woods, occasional; *R. Mohlenbrock 13880.*

Helianthus mollis Lam. Hill prairies, occasional; *J. Voigt 3171.*

Helianthus strumosus L. Woods and fields, common; *R. Mohlenbrock 12966.*

Heliopsis helianthoides (L.) Sweet. Ox-eye. Dry woods, occasional; *R. Mohlenbrock 13926.*

Hieracium gronovii L. Dry woods, common; *R. Mohlenbrock 12695.*

Iva ciliata Willd. Marsh Elder. Waste ground, occasional; *W. Bailey & J. Swayne 2986.*

Krigia biflora (Walt.) Blake. False Dandelion. Dry woods, occasional; *R. Mohlenbrock 148.*

Krigia dandelion (L.) Nutt. Dry woods, occasional; *R. Mohlenbrock 12849.*

Krigia oppositifolia Raf. Moist soil, occasional; *R. Mohlenbrock 12704.*

Krigia virginica (L.) Willd. Dry woods and fields, occasional; *W. Bailey & J. Swayne 3229.*

Kuhnia eupatorioides L. False Boneset. Hill prairies, occasional; *J. Voigt 4446.*

Lactuca canadensis L. Wild Lettuce. Woods and fields, common; *R. Mohlenbrock 12436.*

Lactuca floridana (L.) Gaertn. Dry woods, occasional; *R. Mohlenbrock 13927.*

**Lactuca scariola* L. Prickly Lettuce. Waste ground, occasional; *J. Voigt s.n.*

Liatris aspera Michx. Woods, occasional; *R. Mohlenbrock 12465.*

Liatris cylindracea Michx. Hill prairies, rare; *R. Mohlenbrock s.n.*

Liatris scabra (Greene) K. Schum. Rock slopes, occasional. The type specimen was collected in the Pine Hills by F. S. Earle on September 23, 1890.

Liatris squarrosa (L.) Willd. Dry soil, rare; *J. Voigt 3190.*

Pluchea camphorata (L.) DC. Marsh Fleabane. Swampy ground, occasional; *W. Bailey & J. Swayne 1832.*

Polymnia canadensis L. Leafcup. Woods, occasional; *W. Bailey & J. Swayne 755.*

Polymnia uvedalia L. Bearsfoot. Woods, occasional; *W. Bailey & J. Swayne 1793.*

Prenanthes altissima L. Dry woods, occasional; *R. Mohlenbrock 12752.*

Pyrrhopappus carolinianus (Walt.) DC. False Dandelion. Fields, common; *R. Mohlenbrock 12893.*

Rudbeckia bicolor Nutt. Cherty slopes, rare; *R. Mohlenbrock 14722.*

Rudbeckia hirta L. Black-eyed Susan. Fields and woods, common; *W. Bailey & J. Swayne 2437.*

Rudbeckia triloba L. Brown-eyed Susan. Woods, occasional; *W. Bailey & J. Swayne 2768.*

Senecio aurcus L. Golden Ragwort. Wet ground, occasional; *R. Mohlenbrock 13127.*

Senecio glabellus Poir. Butterweed. Wet ground, common; *W. Bailey & J. Swayne 358.*

Silphium integrifolium Michx. Rosinweed. Hill prairies, occasional; *J. Voigt 2924.*

Silphium perfoliatum L. Cup-plant. Rich open soil, occasional; *R. Mohlenbrock 13879.*

Solidago altissima L. Tall Goldenrod. Woods and fields, common; *R. Mohlenbrock 12406.*

Solidago boottii Hook. Cherty slopes, rare; *R. Mohlenbrock 12965.*

Solidago buckleyi Torr. & Gray. Rocky woods, occasional; *W. Bailey & J. Swayne 867.*

Solidago caesia L. Moist woods, common; *W. Bailey & D. Hankla 633.*

Solidago canadensis L. Fields, common; *R. Mohlenbrock s.n.*

Solidago drummondii Torr. & Gray. Limestone cliffs, occasional; *W. Bailey & J. Swayne 3061.*

Solidago gigantea Ait. Late Goldenrod. Wet ground, occasional; *R. Mohlenbrock 12624.*

Solidago glaberrima Martens. Hill prairies, rare; *J. Voigt 2624.*

Solidago juncea Ait. Early Goldenrod. Fields and woods, common; *R. Mohlenbrock 12703.*

Solidago latifolia L. Broad-leaved Goldenrod. Moist woods, occasional; *R. Mohlenbrock 12435.*

Solidago nemoralis Ait. Field Goldenrod. Fields and woods, common; *W. Bailey & J. Swayne 3187.*

Solidago radula Nutt. Rocky woods, rare; *R. Mohlenbrock 12848.*

Solidago rigida L. Rigid Goldenrod. Hill prairies, occasional; *J. Voigt 3202.*

Solidago speciosa Nutt. Goldenrod. Woods, occasional; *R. Mohlenbrock s.n.*

Solidago strigosa Small. Ozark Goldenrod. Cherty slopes, rare; *R. Mohlenbrock s.n.*

Solidago ulmifolia Muhl. Elm-leaved Goldenrod. Woods, common; *W. Bailey & J. Swayne 886.*

**Sonchus asper* (L.) Hill. Spring Sow Thistle. Waste ground, occasional; *J. Voigt s.n.*

**Taraxacum officinale* Wiggers. Common Dandelion. Waste ground, common; *R. Mohlenbrock 13928.*

Verbesina alternifolia (L.) Britt. Yellow Ironweed. Rich soil, occasional; *R. Mohlenbrock 12466.*

Verbesina helianthoides Michx. Crownbeard. Woods, occasional; *R. Mohlenbrock 12696.*

Vernonia altissima Nutt. Ironweed. Woods and fields, common; *R. Mohlenbrock 14700.*

Vernonia fasciculata Michx. Wet soil, occasional; *R. Mohlenbrock 12753.*

Vernonia missurica Raf. Fields and Woods, common; *W. Bailey & J. Swayne 2703.*

Xanthium chinense Mill. Cocklebur. Moist waste ground, occasional; *R. Mohlenbrock 12619.*

Xanthium commune Britt. Cocklebur. Moist waste ground, common; *W. Stieglitz 34.*

Acknowledgments

This paper is a contribution from the Pine Hill Field Station and the Department of Botany, Southern Illinois University.

Errata

Delete *Acerates lanuginosa* (Nutt.) Dec. and *Rhododendron roseum* (Loisel.) Rehd.

Add *Rhododendron periclymenoides* (Michx.) Shinners, cherty slopes, rare, *Richardson 3, 7; Rhododendron prinophyllum* (Small) Millais, cherty slopes, *Bailey & Swayne 1291; Potamogeton foliosus* Raf., in water, rare, *R. Evers 38626; Potamogeton pusillus*, in water, *R. Mohlenbrock s.n.*

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Mohlenbrock, R. H. 1954. Flowering plants and ferns of Giant City State Park. 16 pp. Department of Conservation and the Illinois State Museum.

Mohlenbrock, R. H., and J. W. Voigt. 1959. A flora of Southern Illinois. Southern Illinois University Press.

Manuscript received March 11, 1965.

NEWS AND COMMENTS

See page 176, issue number 3, volume 57 of the Transactions of the Illinois Academy of Science. That is my plea to authors of papers. I have spent a lot of time changing papers to conform to our format but I cannot continue the practice. It is getting to be too time consuming. For example: when you type the name Jones in the Literature Cited section in capital letters, I need to make three little lines under the "J". If you do not capitalize all the letters, I must put two lines under all the letters along with the third line under the "J". Furthermore, when you, the authors, fail to double space, I have to squeeze those lines in with care.

Another complaint that I must voice concerns the breaking of words at the end of a line. If you do break a word, indicate this by making "close up" marks at the end of the line.
To use the hyphen means the printer will put in a hyphen. I wouldn't object so much about this were it not for the fact that I don't always know whether or not a hyphen properly belongs in that spot.

To me there is a thrill in learning, for the first time, about something that I could have anticipated or deduced had I had my thoughts directed toward the problem. Such was the case with the paper by Rhodes, Courter, and Shurtleff entitled "Identification of Horseradish Types" that appeared in the June issue of the Transactions. I didn't know that horseradish was important. This article hit some of our readers in the same way and they took the trouble to say so to me. I mention this because I want to emphasize to authors that papers published in the Transactions have a wide and diverse audience.

Authors should also know that a "faithful following" read all the articles in order to point out my editorial lapses.

Have you expressed your views on the date of the Annual Meetings (see News and Comments, September issue)?

A member has asked that we have a "Discussion and Reader Comment" section. Presumbably this would be where members could air their views and opinions on the Academy and its parts—particularly the articles in the Transactions. Are you for it?

Have you noticed the amount of "small print" in this issue? Unless the authors and readers revolt, there will be a lot more of it in future issues. This is just another step in meeting our "growing pains."

May I repeat this? NOTES TAKE PRECEDENCE OVER PRINCIPAL ARTICLES IN SPEED OF PUBLICATION.

Dr. Paul W. Parmalee, Curator of Zoology, Illinois State Museum, was promoted to Assistant Museum Director of the Illinois State Museum, on September 1, 1965.

Dr. Parmalee received his B.S. degree from Ohio University in 1948, his M.S. from the University of Illinois in 1949, and his Ph.D. from Texas A. and M. College in 1952; for a study of the life history of the bobwhite quail in the Post Oak Region of Texas.

He joined the Illinois State Museum staff in 1953 as Curator of Zoology where he has built up the taxonomic collection of Illinois fauna to significant and workable tools. He especially strengthened the collections of Mollusca, the Reptiles and Ambhibians, Bats, and the Vertebrate skeletal collections.

He has been particularly effective in the identification of faunal remains from Indian excavations and from cave excavations.

Dr. Parmalee succeeded to the position of Assistant Museum Director, which has been vacant since January 1, 1963 when Milton D. Thompson advanced to the position of Museum Director.

Dickson Mounds was transferred from the Division of Parks and Memorials, Department of Conservation, to the administration of the Illinois State Museum on July 1, 1965.

The site will be known in the future as Dickson Mounds, Museum of the Illinois Indian. It will be developed as a tourist attraction, an educational center for the interpretation of prehistoric man in Illinois, and a research center for the study of Fulton County archaeology.

Governor Kerner has signed a bill authorizing the development of a master plan and architectural drawings and specifications for future capitol improvements for the area.

NOTES

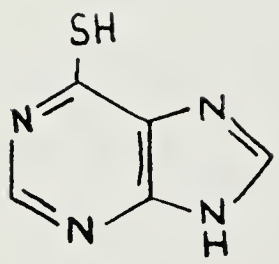
SOME COORDINATION COMPOUNDS OF 6-MERCAPTOPURINE

THOMAS A. DONOVAN
Knox College, Galesburg, Illinois

ABSTRACT.—A number of bis chelates of 6-mercaptopurine with divalent metals have been synthesized and characterized. A presumably dinuclear complex has been isolated with copper (I) thiocyanate.

The coordination chemistry of 6-mercaptopurine has been investigated as part of a general program for a study of the metal-binding specificities of various cancer chemotherapeutic agents which have been suggested for experimental or clinical uses (Ross, 1959, p. 368). The potential anti-cancer activity of 6-mercaptopurine has been widely investigated in recent years (Brockman, 1963, p. 1191) (Elion, 1963, p. 1207). Details of our experimental work are given at the end of this paper.

The structure of 6-mercaptopurine, I, with an ionizable mercapto group *peri* to a tertiary heterocyclic nitrogen atom is formally analogous to that of 8-hydroxyquinoline, II, and the well-known avidity of II for a wide variety of metallic cations (Hollingshead, 1954) suggests that 6-mercaptopurine might be expected to exhibit similar behavior.



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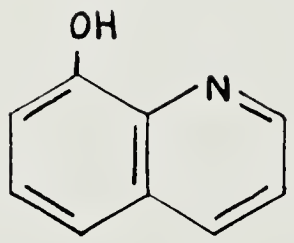

II

However, the coordination chemistry of 6-mercaptopurine has received only slight attention. The most significant investigation was undertaken by Freiser and his coworkers (1959). They determined the aqueous formation constants for complexes of this ligand with Ni(II), Co(II), Pb(II), and Zn(II). No one seems to have reported the isolation and characterization of such complexes.

The synthetic procedure employed in the preparation of divalent metal complexes of 6-mercaptopurine was based upon the general reaction, $M(C_2H_3O_2)_2 \cdot (0\text{-}4)H_2O + 2C_5H_4N_4S \cdot H_2O = M(C_5H_3N_4S)_2 \cdot (0\text{-}2)H_2O + 2HC_2H_3O_2 + (2\text{-}6)H_2O$, where M = Co(II), Ni(II), Zn(II), Cd(II), Hg(II), and Pb(II). Methanol was employed as a solvent with the single exception of the cobalt (II) case in which the use of dimethylformamide was found to yield a purer product. The reactions proceed smoothly and the yields are moderate to high. Purification of the resulting complexes is relatively simple since all of the starting materials and extraneous products are soluble in hot methanol whereas the complexes are insoluble in that solvent. Hence, solvent extraction offers a convenient purification technique.

The complexes attract and hold water tenaciously. Several of the compounds analyze as the dihydrates even after drying for 24 hours in a vacuum at 100°. The nickel (II) compound may be isolated as a monohydrate but, on standing exposed to the air, it readily acquires a second molecule of water.

The actual presence of waters of hydration, as indicated by the elemental analyses, was confirmed by the infrared spectra of these compounds as well as by a study of their thermal stabilities. Thus, the spectra of the hydrated species show strong absorption in the 3400-3500 cm^{-1} region whereas this region is empty in the case of anhydrous species. More convincing, since several of the spectra were run after exposure of the sample to air, were thermal stability studies which showed that each of the hydrated species lost 5-10% of its initial weight at 200°. This loss corresponds to the removal of 1-2 water molecules. In most cases there is a plateau of relative stability beyond this point, extending as high as 350°.

All of the complexes are soluble with decomposition in strong acids or bases and relatively insoluble in water and most polar organic solvents.

6-Mercaptopurine, in the manner common to thiol ligands, reduces copper(II) to copper(I) prior to complex formation. In order to avoid the complications inherent in such a stepwise reaction, a copper (I) complex of 6-mercaptopurine was prepared by the direct reaction of copper(I) thiocyanate and the ligand. The reaction proceeds slowly in methanol and is characterized by a gradual color change from pale yellow to deep cherry red. The product isolated after 24 hours analyzes as a 1:1 adduct, $Cu(C_5H_4N_4S)$ (SCN). This species is diamagnetic. It may be a dimer with thiocyanate bridges but no suitable solvent for a molecular weight determination has been found. Hence, full characterization of this species must await further study.

Procedures

Thermal stability studies were conducted with a simple thermogravimetric balance constructed by Judd (1958). Infra-red spectra were obtained as KBr disks and fluorolube mulls using a Beckman Model IR-5 spectrophotometer.

Sythesis of bis (6-mercaptopurinato) lead (II) .-6-Mercaptopurine hydrate (0.68 g, 0.004 mole) was placed in a 500 ml., one-necked, round-bottom flask and dissolved with 200 ml. of absolute methanol. Lead acetate trihydrate (0.76 g, 0.002 mole) was added to the solution and the mixture was slurried with a magnetic stirrer. The flask was equipped with a water-cooled condenser and the mixture was placed under gentle reflux. After 24 hours the reaction mixture was filtered. The chunks of yellow solid product were ground to a powder, placed in a Soxhlet extractor, and extracted with hot methanol for 24 hours. The yield was 1.00 g (82%). (Analysis: Calculated for $C_{10}H_6N_8S_2Pb$: C, 23.57; H, 1.19; N, 21.99. Found: C, 23.59; H, 1.58; N, 21.83).

The following compounds were prepared under conditions similar to the formation of bis (6-mercaptopurinato) lead (II):

bis (6-mercaptopurinato) mercury (II), yield 94%. Analysis: Calculated for $C_{10}H_6N_8S_2Hg$: C, 23.88; H, 1.20; N, 22.28. Found: C, 23.85; H, 1.33; N, 21.90.

bis (6-mercaptopurinato) cadmium (II) dihydrate, yield 75%. Analysis: Calculated for $C_{10}H_6N_8S_2Cd \cdot 2H_2O$: C, 26.64; H, 2.24; N, 24.86. Found: C, 26.51; H, 1.81; N, 24.68.

bis (6-mercaptopurinato) zinc (II) dihydrate, yield 67%. Analysis: Calculated for $C_{10}H_6N_8S_2Zn \cdot 2H_2O$: C, 29.75; H, 2.50; N, 27.75. Found: C, 29.84; H, 2.05; N, 28.26.

bis (6-mercaptopurinato) nickel (II) monohydrate, yield 87%. Analysis: Calculated for $C_{10}H_6N_8S_2Ni \cdot H_2O$: C, 31.69; H, 2.13; N, 29.56. Found: C, 31.73; H, 2.56; N, 29.75.

Synthesis of a copper (I) complex of 6-mercaptopurine 6-Mercaptopurine hydrate (1.10 g, 0.006 mole) and copper (I) thiocyanate (0.36 g, 0.003 mole) were slurried in 200 ml. of absolute methanol in a 500 ml. one-necked, round-bottom flask. The flask was equipped with a water-cooled condenser and the mixture was placed under gentle reflux. After 24 hours the mixture had changed from a pale yellow hue to a bright cherry red. The solid product was filtered, extracted with hot methanol for 24 hours and dried *in vacuo* for 24 hours. The yield was 0.78 g (93%). (Analysis: Calculated for $C_5H_4N_4S \cdot Cu$ SCN: C, 26.32; H, 1.47; N, 25.58. Found: C, 26.38; H, 1.44; N, 25.51).

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MYXOMYCETES NEW TO ILLINOIS

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ABSTRACT.—A survey of the Myxomycete flora of Montgomery Arboretum (Northern Illinois University) and collecting sites in Cook and Kane Counties, Illinois yielded eleven species and two genera not previously reported from Illinois.

The myxomycetes of Illinois have been the subject of only two previous papers. Stover (1941) reported the occurrence of thirty-six species in the area immediately surrounding Charleston. After an extensive survey of the slime molds of Champaign County (Benjamin, 1949) and some spot collecting in other sites in the State, Benjamin (1956) reported the occurrence of 133 species in 35 genera.

During the period between the summer of 1962 and the fall of 1964, the junior author conducted a survey of the Myxomycete flora (McCleary, 1965) of a six acre plot of woods known as the Montgomery Arboretum located on the campus of Northern Illinois University, DeKalb. In addition to field collections extensive use was made of the moist chamber culture technique first used by Gilbert and Martin (1933). Pieces of bark from living trees were placed on filter paper in petri dishes and soaked with distilled water. After 24 hours the water was removed and the cultures were allowed to stand for about two weeks. At the end of this time, the covers were removed and the bark examined for the presence of Myxomycete fruiting bodies and plasmodia. If the examination revealed no fruiting bodies or plasmodia the culture was remoistened and examined after another two weeks. Bark examined was obtained from trees in the Montgomery Arboretum and trees on the west side of the 2100 block of 21st Avenue, Broadview, Illinois.

Sixty eight species were found. The identifications were based on Martin's (1949) monograph in *North American Flora*. Verifications were made by Dr. G. W. Martin, University of Iowa and Dr. C. J. Alexopoulos, University of Texas. All species have been deposited in the Myxomycete collection at the University of Iowa, Iowa City. When available, duplicates were deposited in the herbaria of the University of Illinois, Urbana; Northern Illinois University, DeKalb; University of Texas, Austin; and the Chicago Natural History Museum, Chicago.

The collection sites and substrate of the species new to Illinois are as follows:

Arcyria magna Rex. Montgomery Arboretum, DeKalb Co. Dead wood and bark of *Ulmus* sp. Benjamin (1949) mentions two Illinois collections of this species in the herbarium at the University of Iowa, but does not include the species in his check-list (Benjamin, 1956). Dr. Martin placed our specimen as being between *A. magna* and *A. oerstedtii* Rost. The translucent and iridescent cups and the long expanded capillitium fit the description for *A. magna* (Martin, 1949).

Badhamia panicea (Fries) Rostafinski. Cook County Forest Preserve, Maywood (behind Proviso East High School), Cook Co. Dead wood and bark.

Calomyxa metallica (Berk.) Nieuwl. = *Margarita metallica* (Berk.) A. Lister (Martin, 1961). Montgomery Arboretum, DeKalb Co. Dead wood. Dr. Martin noted that the single specimen collected was the first stalked form of this species that he had seen. This is the first report for the Family Dianemaceae and the genus *Calomyxa* in Illinois.

Comatricha lurida A. Lister. Montgomery Arboretum, DeKalb Co. Rotting wood. Dr. Martin indicated that the slight variations found in the specimen were well within the range of variation seen in the species.

Cribraria aurantiaca Schrad. Montgomery Arboretum, DeKalb Co. Rotting wood.

Cribraria languesceus Rex. Montgomery Arboretum, DeKalb Co. Rotting wood.

Licea operculata (Wingate) G. W. Martin. Montgomery Arboretum, DeKalb

Co. Moist chamber culture on bark of *Ulmus* sp. Single typical collection of 10 fruiting bodies.

Licea pedicellata (H. C. Gilbert) H. C. Gilbert. Montgomery Arboretum, De Kalb Co. and Broadview, Cook Co. Moist chamber culture on bark of *Juglans nigra* and *Ulmus americana*. Spores tended to be larger than described and more uniform in color.

Lindbladia effusa (Ehremb.) Rostafinski. Johnson Mound Forest Preserve, Kane Co. and Montgomery Arboretum, DeKalb Co. Rotting wood. This is the first report for this genus in Illinois.

Stemonitis nigrescens Rex. Montgomery Arboretum, DeKalb Co. Rotting wood.

Stemonitis smithii Macbr. Montgomery Arboretum, DeKalb Co. Rotting wood.

This paper brings the number of species of Myxomycetes reported from Illinois to 144. Two previously unreported genera, *Lindbladia* and *Calomyxa (Margarita)*, are reported bringing the number of genera found in Illinois to 37. Almost all of the reported species have been collected in the central and northern parts of the State.

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